TELESCOPE MAKING 24

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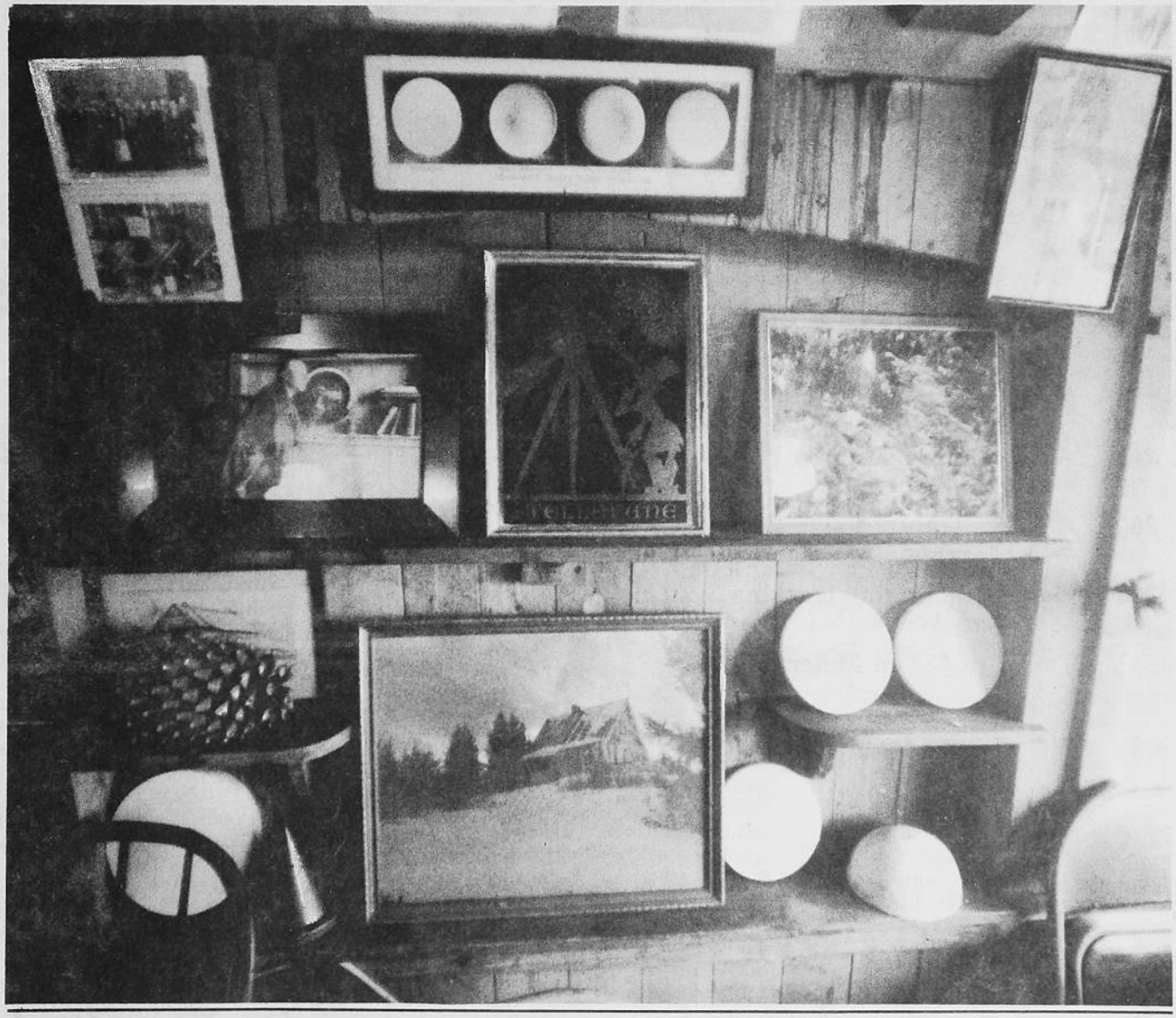

Honoring Fifty Years of Stellafane History

TELESCOPE MAKING

The magazine *for, by,* and *about* telescope makers!

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Cover: The west wall of the "little pink house on the hill" at Stellafane.

Editorial

Another issue of *Telescope Making* has just filled its allotted pages — and I find myself looking at a distressingly large back file of articles, several lengthy galleys of type hanging on the wall, and numerous pictures and cartoons that simply won't fit into TM#24 no matter what I do about it.

But don't worry — they'll be published. Although it might not be in this issue, I want to assure waiting authors — you know who you are — that your articles are destined for TM. Once in a while, somebody asks how I decide what will and won't go into a particular issue. The answer I give is: "I consult an excellent professional editor — me — and follow his advice without fail."

TM generally runs the most topical articles first. Included in this issue, for example, are articles by D. Eric Allen, Tom Osypowski, and Lee Cain. Their articles result from my meeting them this spring. Eric Allen's stubby fork is quite possibly the most important development to come "down the pike" in several years, because Allen has managed to build Dobsonian stability into a plywood and Teflon equatorial. I expect that his telescope will be widely imitated in the next several years. Tom Osypowski has further paved the path toward "equatorializing" the big instruments many amateurs now have with a platform setup nearly ideal for serious visual deep-sky observing.

Duplicating Lee Cain's binocular is a bigger task than I'd care to undertake

myself, but the instrument has attracted a great deal of notice. I hope that Lee has answered all the most obvious questions in his article and pictures.

Planned — but not running in this issue — are excellent articles by Sherman Shultz and Bob Cox: the first on determining the size of your eye's pupil and the second on tube currents in telescopes. Both contain important information and both will run in TM#25; the decision to hold them was based largely on how well the information will "keep."

The "Fifty Years of Stellafane" pictorial was run not for its timeliness, but as a tribute to the people who started it all. Bob Cox and I combined our photo files to cover much of Stellafane's history. For TM readers new to the tradition of telescope making, consult *ATM Books I, II,* and *III.* You will recognize many objects (the plaster mirror profiles, for example) which are still up there in "the little pink house on the hill." I hope that 50 years hence, those who follow us will find the mementos of our activities equally fascinating.

Next topic: Over the years, we've had problems with equations in TM. I've tried a variety of ways of reproducing them, but given that Kate and I have a limited amount of time to spend on it and math is notoriously difficult to proofread, nothing we've tried has ever proven error-free. But there is a way. Henceforth, we are asking anyone submitting an article with equations in it to supply the equations typed on a separate sheet of paper. We will "stat" them directly from your copy — untouched by typists, typesetters, or editorial hands. Dot matrix printout is not acceptable for equations, even though it is adequate for program listings. As in scientific publications, the correctness of an article's math becomes the direct responsibility of the author.

Next topic: Telescope Making has always been a child of the electronic age — edited as it is on a word processor, then transferred electronically into our typesetter and typeset. TM recently bought its own modem so that Bob Cox and I can send text over the phone lines, thus saving — hopefully — a lot of retyping. We're now taking the next logical step: TM will accept articles via CompuServe's EMAIL as well as two floppy disk formats. The details: Floppy formats we can accept are 5¼" IBM PC diskettes, 9 soft-sector, created on MS/DOS 2.10 or anything compatible with it, and the Vector Graphic 5¼" 16-hard-sector, double-sided, quad-density diskette created under CP/M Version 2.2. This latter format is rather rare, but it's what we use. Text files must be ASCII, stripped of all word processor codes, embedded formatting and printer commands, and preferably not line oriented. We'll return your disk after copying the article text file.

On CompuServe, our user ID is 74206,110. You can split an article into EMAIL-size chunks (about 4,000 characters) and send it as five or six "letters," or arrange to transmit it directly to our office in Milwaukee. This last arrangement is not the best since we can't guarantee having a computer free on short notice (they're in demand most of the day). We'll be expecting ASCII data at 300 baud with 7 data bits, 1 stop bit, and even parity — the same parameters most people use with CompuServe. If this experiment works, we'll get a 300/1200 baud system to receive manuscripts and leave it running on auto in the evenings.

Next topic: We're planning TM#26 as a topical issue on Dobsonians. Why? It's time for summing up what we've learned about these big-aperture beasties.

A few weeks ago at the Milwaukee Astronomical Society's annual dark-sky camp-out weekend, observers who showed up brought with them one equatorial Newtonian reflector, two Schmidt-Cassegrains, five Dobsonian Newtonians, and a Dobsonian-mounted RFT refractor. So what's new?

Well, five years ago there would have been no Dobsonians.

And now, today, the "revolution" having passed its peak, Dobsonians assume a legitimate place among the choices open to telescope builders and observers.

There are a few hold-outs, of course, who claim Dobsonians have no value at all — but these folks have closed minds. There are others who claim that nothing's as good as a good Dobsonian, and these folks suffer from equally narrow ideas. The truth lies somewhere in-between and is far more complex.

Of course, the nay-sayers have a point — there are poorly constructed Dobsonians. But I've also seen superb Dobsonians, just as I have seen excellent Cassegrains and botched Cassegrains. And though I've seen bad optics, I've also seen excellent optics. People have even managed to make wobbly Dobsonian mountings, which is truly some sort of proof of the range of human enterprise!

So what if the tidal wave is over. A reasonable person setting out to build a telescope will now choose a Dobsonian for certain well-defined reasons. Ease of construction. Aperture. Portability. Serious deep-sky observing. Cost. Reasons compelling enough to explain the popularity of the design. The Dobsonian is the answer to certain observing requirements.

It *is* possible to deny the validity of visual deep-sky observing. I've even heard people do it. I would hesitate to say, categorically, that these are people who lack poetry in their souls, but some of them . . .. And I've heard people claim that *all* Dobsonians have seagull-shaped images and are therefore useless, but I'll bet they've never offered to help collimate the telescopes with the seagulls. I've seen seagulls, too. Proper collimation removes them.

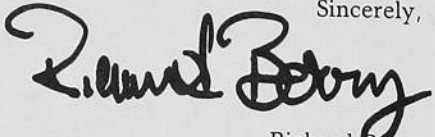
Part of their reaction is that Dobsonians are threatening. They're too big, and they expand the range of purpose in amateur astronomy too much. They overturn the natural order and open a "whole new ballgame" in observing. We have learned that we can see sky objects that a decade ago were considered all but unseeable — objects like the Veil Nebula.

But on the down side, we're still discovering what it means to bring an observatory-sized instrument to a site that no reputable astronomer would recommend — sites with five arc-second seeing. We have found, and exceeded, the limits of portability. And we are still learning — in some cases the hard way — that fast large-aperture telescopes require careful mirror support, accurate collimation, and good tube temperature control.

Well, that's what we get for breaking the 10" aperture barrier. It's worth learning what it takes to solve the problems.

But back to the topic: We're asking for contributions — letters, postcards, photos, articles, or whatever — for a topical TM#26, Spring 1985, on optimizing Dobsonians. Let's pool our experience in building and using these telescopes and share what we've learned. Items I'd especially like to see are mirror support experiments, using "odd" glass (including experiments that didn't work), good bearing material combinations, sources of tubes, cheap Teflon and where to get it, a good alt-az set-up program in generic BASIC (find three stars, read circles, calculate transformations, thereafter compute el and az, then dial in objects) — the list could go on and on. Big articles. Short notes. Letters. Don't think your contribution too small or too unimportant — I want to hear from you.

Sincerely,



Richard Berry
Editor

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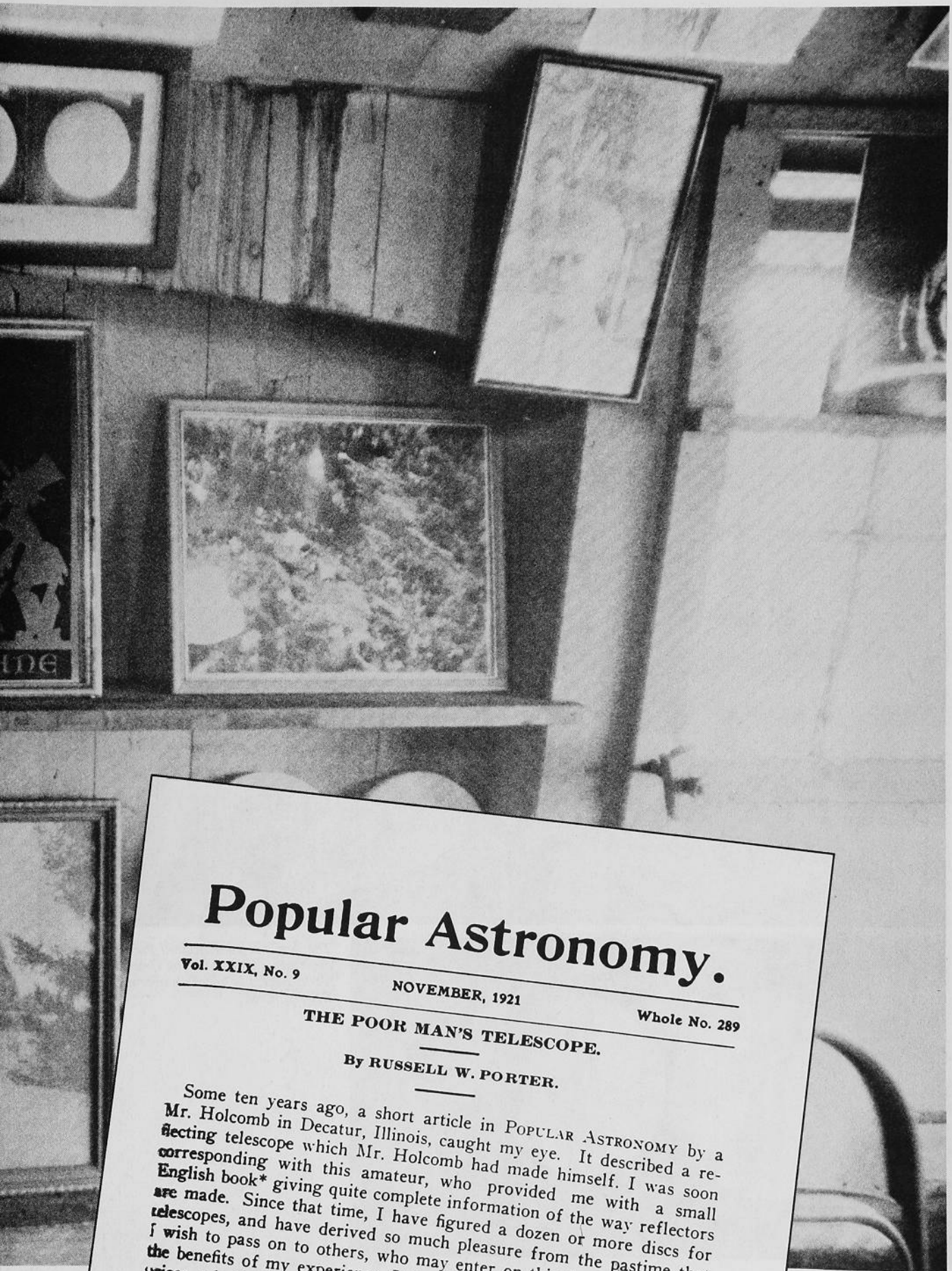
Fifty Years of Stellafane



Popular Astronomy.

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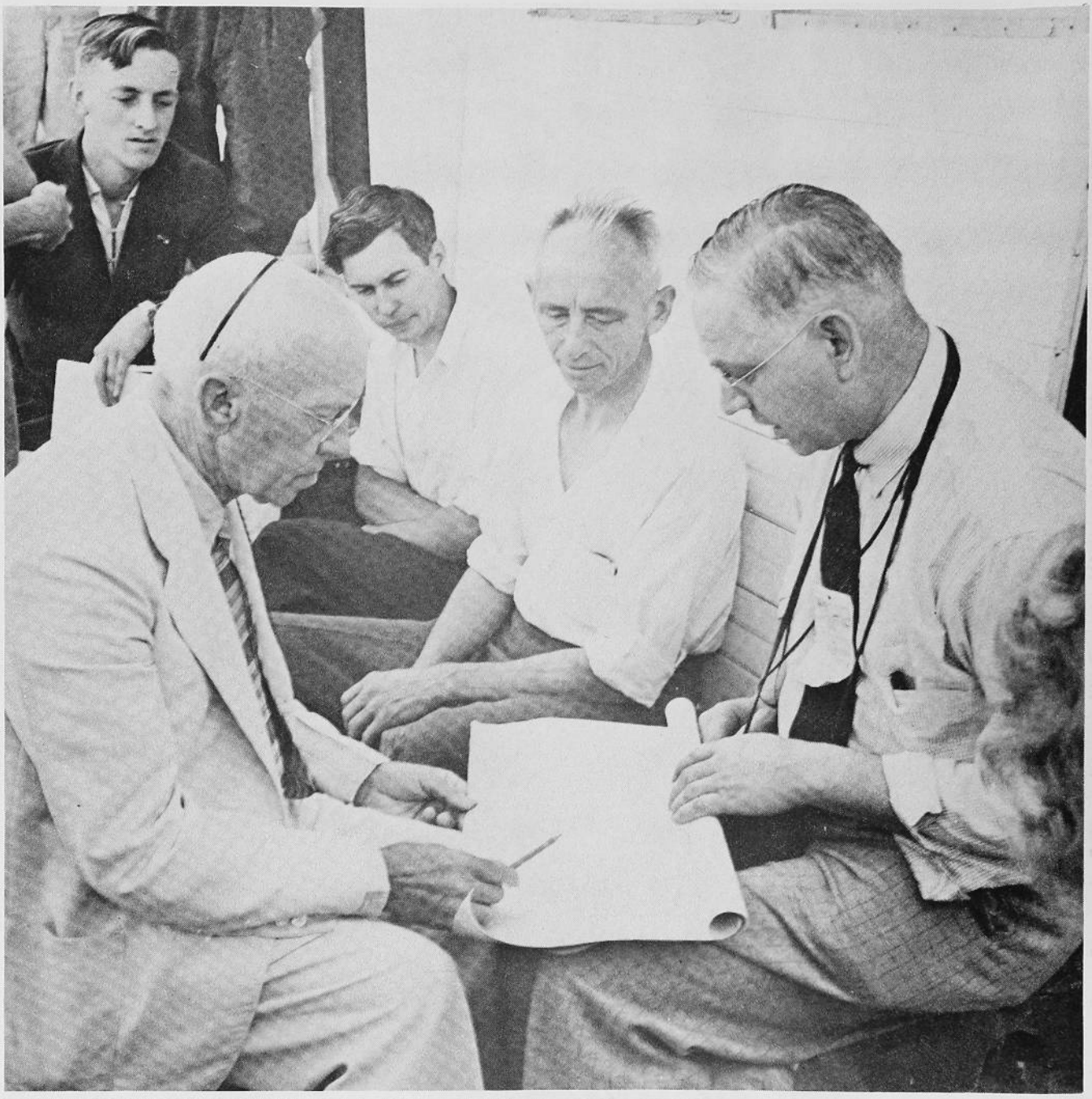
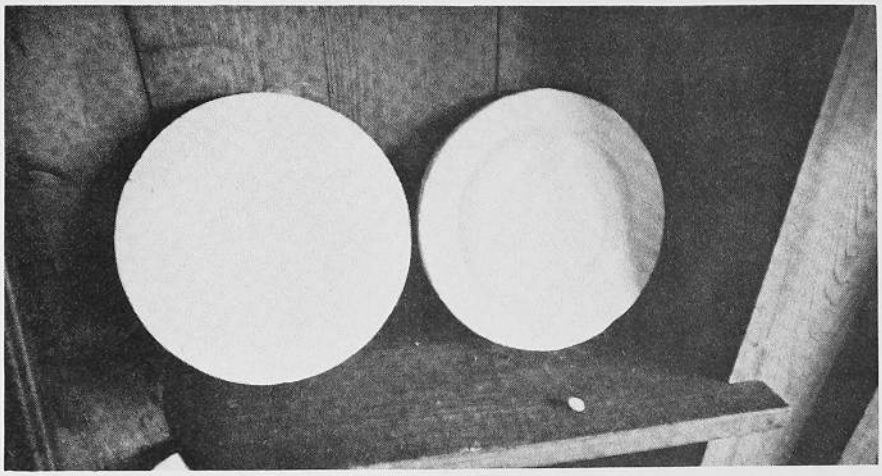
THE POOR MAN'S TELESCOPE.

By RUSSELL W. PORTER.

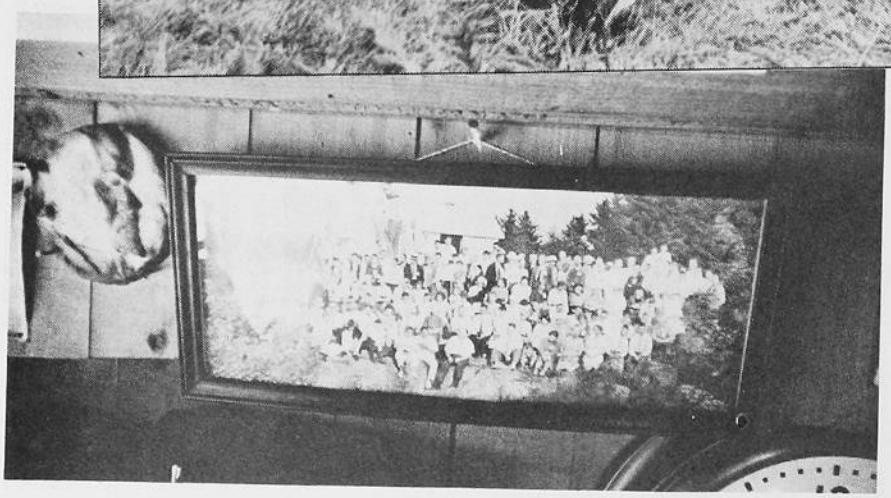
Some ten years ago, a short article in POPULAR ASTRONOMY by a Mr. Holcomb in Decatur, Illinois, caught my eye. It described a reflecting telescope which Mr. Holcomb had made himself. I was soon corresponding with this amateur, who provided me with a small English book* giving quite complete information of the way reflectors are made. Since that time, I have figured a dozen or more discs for telescopes, and have derived so much pleasure from the pastime that I wish to pass on to others, who may enter on this fascinating work, the benefits of my experience. It is really remarkable, considering the prices asked for telescopes to-day, that one possessed with a little time can produce a very [illegible] at so small a cost. [illegible]



The year was 1937. Russell Porter dicusses observatory plans with Jim Grant of New York. Behind is famous mirror-maker Wally Everest. (Cox)



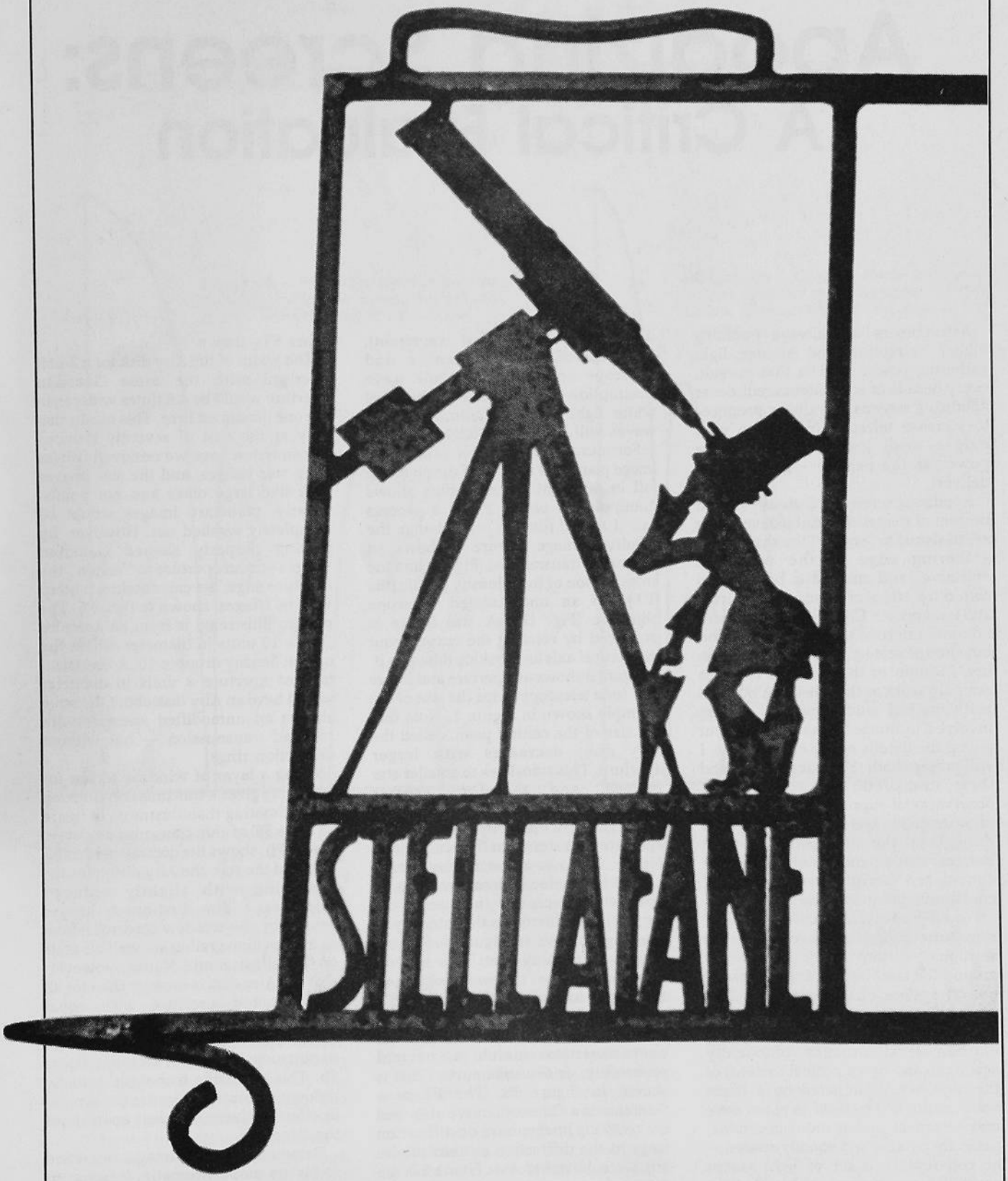
After the war, Stellafane resumed. In 1948, Dr. Henry Paul and members of the New York club posed with Paul's 90° wide-angle camera built around a surplus Metrogon. (Cox)



The 50s brought refinements in design, exemplified by this stable yet portable equatorial. (Cox)

The 60s saw the use of commercial telescope parts and an upsurge of interest in astronomy and space.

Crowds have been bigger and telescopes more plentiful than in earlier years — but the spirit of Stellafane remains in the 80s.



Cox photo

Apodizing Screens: A Critical Evaluation

Astronomers are always pursuing higher resolution and greater light gathering power, and in that pursuit, every decade or so amateurs rediscover apodizing screens. Apodizing promises to increase telescope resolution with only a small loss in light-gathering power as the penalty — but does it deliver?

Apodizing screens are usually placed in front of the telescope objective. They are designed to "soften" the sharp light-gathering edge of the telescope objective, and may also be used to soften the edges of a secondary mirror and its supports. Claims that the screens not only improve telescopic resolution but also the seeing, have been made. An investigation of these claims involves not only work at the telescope but also mathematical studies of the process involved in image formation. Without giving the details of the calculations, I will present both theoretical results and their interpretation, and present observational support from visual and photographic tests. Keep in mind throughout the discussion of point sources, that extended objects may be considered simply collections of contiguous point sources.

We all know that the "diffraction" rings surrounding the image of a star are spurious — they aren't in the sky around the star, but are formed by the optical system of the telescope. This occurs because the image of the star is the Fourier Transform (FT, a mathematical process physically accomplished by an optical system) of the objective illuminated by a plane wave, multiplied by itself. A plane wave may be envisioned as monochromatic, perfectly parallel and equally-spaced — or coherent — a set of light waves emitted by a source. Although light from a star is not a plane (since it is polychromatic and emitted in all directions as a spherical wavefront), over astronomical distances and telescope apertures the plane wave assumption is valid. The problem of white light and seeing-limited plane waves will be covered later.

For sources not at optical infinity, the image plane and the FTs of the objective fall in different places, which allows manipulation of the FT — a process called *spatial filtering* — to change the resulting image. Figure 1 shows an aperture's transmission (Fig. 1a) and the cross section of the intensity profile (the $[FT]^2$) of an unobstructed telescope objective (Fig. 1b). A star image is produced by rotating the curve about the vertical axis and looking down on it.

Figure 2 shows an aperture and image pair for a telescope twice the size of the example shown in Figure 1. Note that the size of the central peak, called the *Airy disk*, decreases with larger aperture. This translates to smaller star images, and therefore greater resolution.

Images formed by obstructed apertures are shown in figures 3 and 4. Figure 3 shows a small obstruction typical of amateur telescopes. A large obstruction decreases the size of the Airy disk and increases the intensity of the rings, shown in Figure 4. So far I have said nothing that TMs haven't observed many times, using their telescopes to perform the FT.

Now suppose an apodizing screen is introduced whose transmission characteristics match a normal probability, or *Gaussian* curve. This is shown in Figure 5a. The FT of a Gaussian is a Gaussian curve also, and the resulting images have no diffraction rings in the diffraction pattern (figure 5b). Note, however, that Figure 5 is the pattern for an aperture whose diameter is 9.6 units (at an optical density of 10), not the 2 units of clear aperture for the other FTs shown.

The width of the Airy disk for a 2-unit aperture with the same Gaussian aperture would be 4.8 times wider than the one illustrated here. This means that only at the cost of severely reduced transmission have we removed fringes from star images, and the star images look like large disks and not points. Clearly, planetary images would be completely washed out. However, by putting properly shaped Gaussian "edges" on an aperture to "soften" the aperture edge, we can obtain a pattern with no fringes, shown in figure 6. The pattern illustrated is from an aperture that is 10 units in diameter where the optical density drops to 10. A Gaussian-tapered aperture 2 units in diameter would have an Airy disk about the same size as an unmodified aperture with reduced transmission — but without diffraction rings.

Using a layer of window screen for apodizing gives a transmission function approximating that illustrated in figure 7a. The FT of this transmission curve, Figure 7b, shows the central, zero order image of the star, the Airy disk, plus the first ring with slightly reduced brightness. (The first-order images caused by the window screen's action as a diffraction grating are well off-scale on this illustration.) Notice, however, that the Airy disk is broader than for an unobstructed aperture with equal overall diameter, and that it closely matches that of a 1.4 unit diameter unobstructed aperture, shown in figure 8b. This apodizing technique actually reduces resolution because the screen, in effect, reduces the clear aperture of the telescope.

Remember that the images discussed so far are monochromatic. It turns out that with white starlight entering the telescope, the patterns illustrated will be the same, since the starlight is

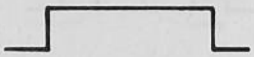


Figure 1a — *Sketch of transmission along a diameter of an unobstructed aperture two units in diameter.*

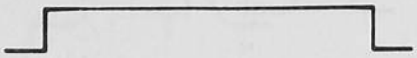


Figure 2a — *Sketch of transmission along a diameter of an unobstructed aperture twice the size of that in Figure 1a.*

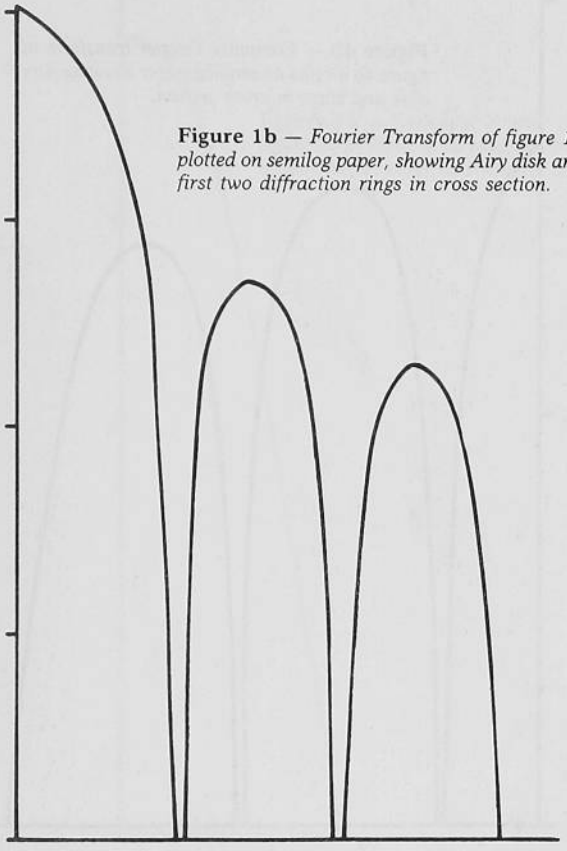


Figure 1b — *Fourier Transform of figure 1a plotted on semilog paper, showing Airy disk and first two diffraction rings in cross section.*

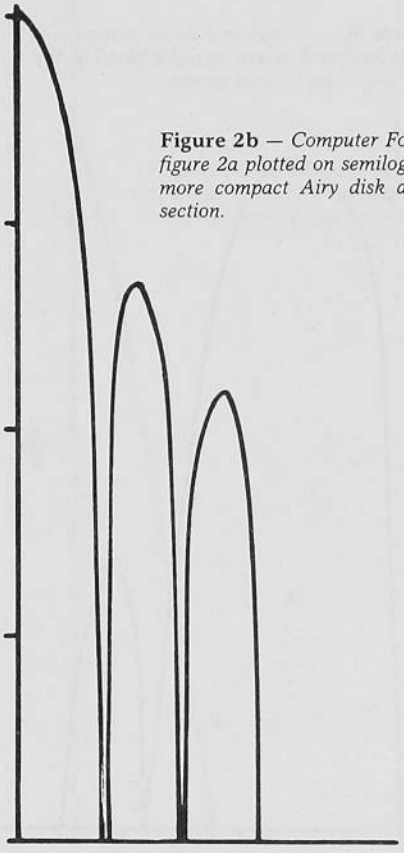


Figure 2b — *Computer Fourier transform of figure 2a plotted on semilog paper, showing a more compact Airy disk and rings in cross section.*

sufficiently coherent to be treated as a plane wave. Only the pattern resulting from a window screen apodizer is different in white light: the first-order images appear as rainbow-colored radial spectra well away from the Airy disk (the zero-order). The number and direction of radial spectral bands vary according to the window screen type and layout used to make the apodizing screen.

To summarize the results so far, mathematical analysis of apodizing screens shows that they modify the image produced by a telescope objective. Some apodizing screens have the potential to improve the contrast of an image by removing diffraction rings, which will improve the views of planets and close binary stars. *Simple apodizing screens made of window screen actually reduce the resolution.*

What happens when an atmosphere with moving air parcels of different densities and temperatures is placed between a telescope (with or without an apodizing screen) and the plane waves coming from a star? The wave front is no longer flat and some portions come to a focus in one place, other portions in another place — "seeing" smears the Airy disk into a pattern of image *speckles*. It is possible to see speckles in the highly magnified seeing disks of bright stars with amateur telescopes.

For a planet, bad seeing causes even more problems. Since plane waves from any object point do not all come to focus at a corresponding image point, but instead fall on other image points, the contrast and resolution are lost. It doesn't matter what apodizing screen is placed before the objective: the screen cannot correct the distorted wavefront caused by the atmosphere. The so-called active optics, where a computer-controlled mirror is rapidly "refigured" to compensate for the wavefront distortions, will have this capability.

(As an aside: Speckle interferometry succeeds despite imperfect seeing — by means of short exposures and nearly monochromatic light. For highly magnified photos of the smeared Airy disk, see *S&T*, July 1971, pp. 11-12 and March 1975, pp. 164-165. These photos show the constructive and destructive interference of light waves coming from various areas of the objective. Speckle images can be used to construct diffraction-limited images of close double stars and to resolve surface detail on giant stars.)

I confirmed the invariance of "seeing" using an excellent quality Celestron 1250mm f/10 telephoto lens

Figure 3a — *Sketch of transmission along a two-unit diameter of an aperture with a central obstruction over 30% of the diameter.*

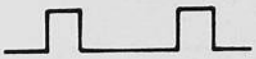


Figure 4a — *Sketch of transmission along a two-unit diameter of a 60% obstructed aperture.*

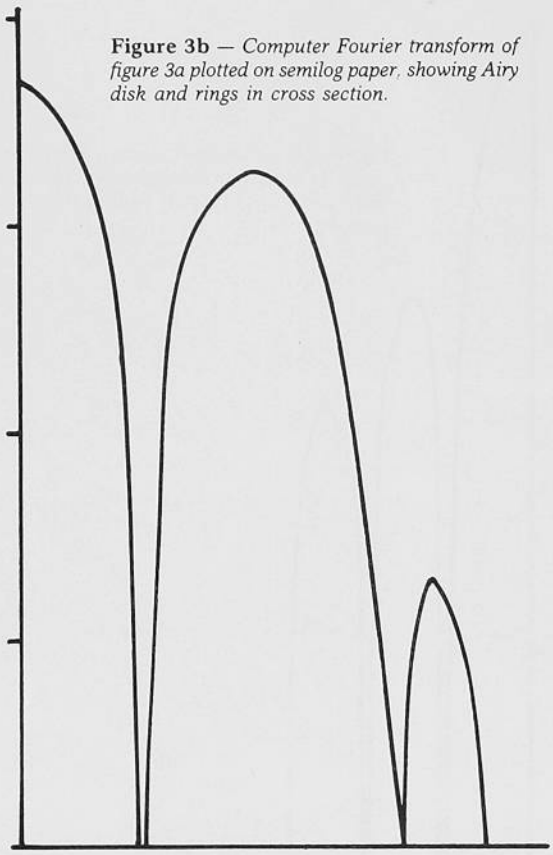


Figure 3b — *Computer Fourier transform of figure 3a plotted on semilog paper, showing Airy disk and rings in cross section.*

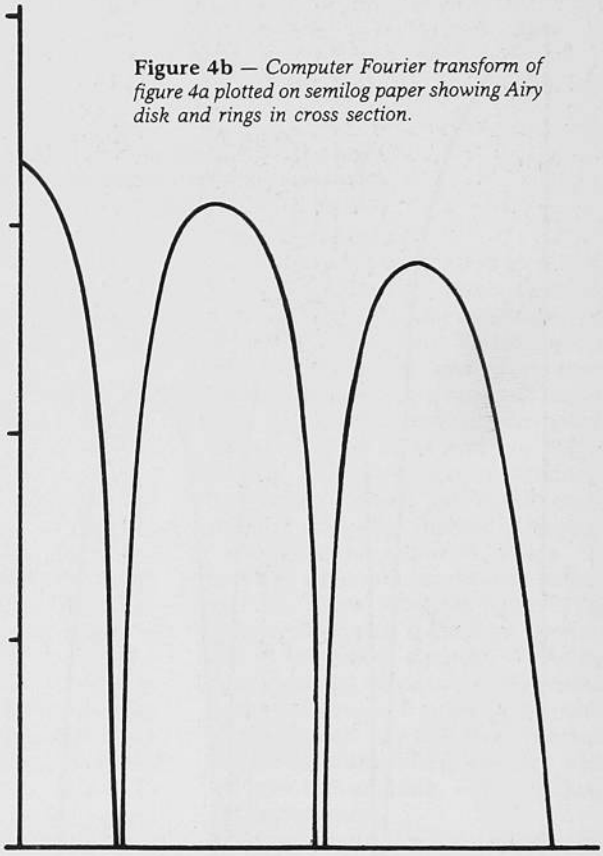


Figure 4b — *Computer Fourier transform of figure 4a plotted on semilog paper showing Airy disk and rings in cross section.*

to photograph star trails perturbed by seeing. On a night of average to poor seeing at the Polaris Observatory Association site in Lockwood Valley, California, the telephoto was mounted on a tripod and aimed at stars near the horizon and near the zenith. Various apodizing screens, aperture stops, and full aperture (see the following table for details) were used in front of the telescope to produce the trailed images. Besides the variation in the intensity of the trails, due to the differing transmissions of the screens and stops, the most striking result is that all the trails show the same amount of seeing-caused image motion.

Visual lab tests were also conducted. The telephoto was tripod-mounted and aimed at an unmasked circular portion of a rear-illuminated USAF test target that mimicked a planet (with high contrast surface detail) seen against dark sky. The sharp, high-contrast edges show exactly what happens to the image when the entrance aperture is modified. A hair dryer provided artificial "poor seeing" when directed about 20 inches in front of the telephoto.

When the "poor seeing" was turned on, images apparently improved when the entrance aperture was modified. The seeing was least troublesome with a 3.5″ stop, and was better with the 3.5″ stop than with a 3.5″ screen. The seeing itself was not improved by the smaller apertures, but was less annoying. Visually, short periods of stability were more frequent with the smaller aperture, and with both stops, they occurred more frequently than with the corresponding screens. This is not surprising since the screens transmit some light across the full aperture.

In making tests with the poor seeing turned off, it was necessary to use a magnification that just resolved the bars on the test target at the limit of the telescope's performance. *Higher magnification was "empty," and lower would not show the effects of the screens and stops.* Compared to the full 5″ clear aperture, both the 4.5″ screen and stop had no noticeable effect on the resolution.

The 3.5″ screens showed a small reduction in resolution, and the 3.5″ stop showed a definite decrease. These observations verify that resolution depends on the diameter of the aperture contributing light to the image, even when the light from the outer zones is reduced. They also suggest that when

Figure 5a — *Sketch of transmission along a 9.6 unit "diameter" of an aperture with Gaussian transmission characteristics. The Airy disk is very broad for a two-unit diameter Gaussian aperture.*

Figure 6a — *Sketch of transmission along a 10 unit "diameter" of an aperture whose edges have a Gaussian taper starting at 0.8 of the radius.*

Figure 5b — *Computer Fourier transform of figure 5a plotted on semilog paper. There are no diffraction rings surrounding the disk.*

Figure 6b — *Computer Fourier transform of figure 6a plotted on semilog paper. There are no diffraction rings surrounding the disk.*

lower magnification is used, as under poor seeing conditions, any benefit of even an ideal apodizing screen will not be seen because insufficient magnification is used. The seeing smears out detail so even optimum magnification with a screen would show smeared images and no increase in resolution.

Both visual laboratory tests under good and poor seeing and photographic sky tests agree with theoretical arguments. They show that seeing is not actually improved by an apodizing screen even though an *apparent* improvement due to the reduced clear aperture may be observed. The laboratory tests also indicate that except in *perfect* seeing, when a telescope can be used at its maximum performance in magnification, an apodizing screen will do little to improve the view.

However, visual observations of planets made on a night of poor seeing in Tujunga, California showed an apparent improvement in planetary detail when using a screen. Poor seeing remained poor with an apodizing screen, but detail seemed easier to see. Aside from affecting what I call the "image contrast," as discussed earlier, the screen strongly affects the "field-of-view contrast." At the same time the intensity of the planetary image was reduced (lost light going into the surrounding spectra), contrast between planet and sky decreased the amount of glare, making planetary detail easier to see. Reducing FOV contrast has long been a favored technique of planetary observers studying Venus in twilight. They use the bright sky to decrease the contrast instead of darkening the planetary image. I also tried using a neutral density filter over the eyepiece with an unmodified entrance aperture and found it had the same effect, reducing the glare and making planetary detail easier to see.

So how do we explain the testimony of expert observers who claim apodizing screens improve the resolution or seeing? Six possibilities come to mind, which separately or together may help to explain apodizing:

1) The Questar effect, wherein a small aperture gives a steadier image in poor seeing than a large aperture. In effect, the apodizing screen acts primarily as an aperture stop, reducing the effective size of the objective. My tests support this conclusion.

2) A poor figure on the outer zones of

Figure 7a — *Sketch of transmission along a two-unit diameter of an aperture using window screen as an apodizer starting at 0.7 of the radius. The screen holes were scaled to match a total diameter of one unit. There should be thirteen peaks outside the central rectangle.*

Figure 8a — *Sketch of transmission along a diameter of an aperture 1.4 units in diameter.*

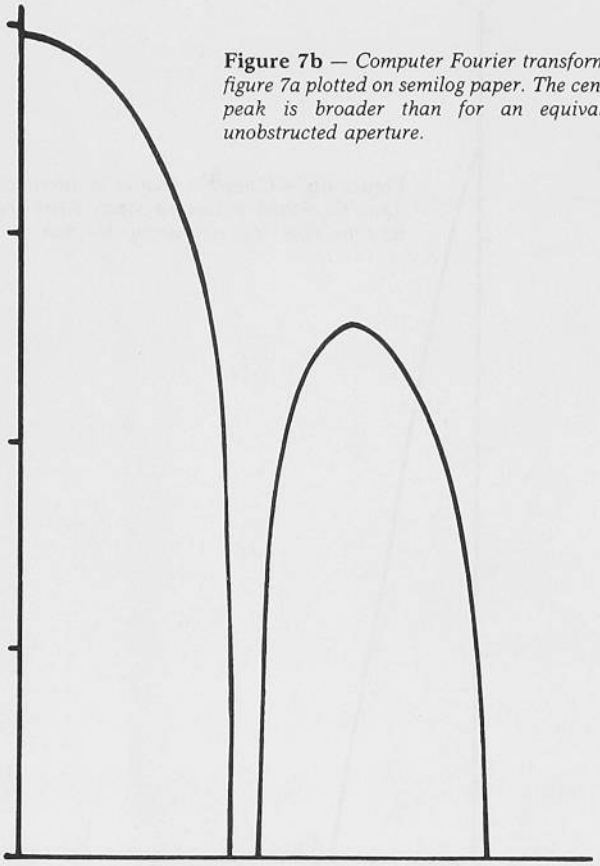


Figure 7b — *Computer Fourier transform of figure 7a plotted on semilog paper. The central peak is broader than for an equivalent unobstructed aperture.*

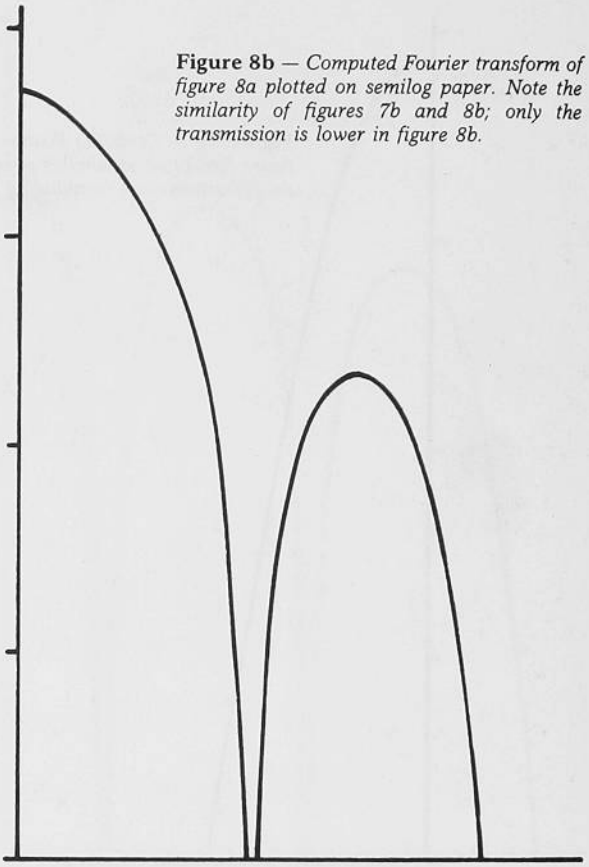


Figure 8b — *Computed Fourier transform of figure 8a plotted on semilog paper. Note the similarity of figures 7b and 8b; only the transmission is lower in figure 8b.*

the objective. An apodizing screen acting as an aperture stop would again be beneficial. S. Greenberg suggests that bad seeing due to air currents along the tube wall might also be reduced by the screen.

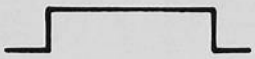
3) A well-designed Gaussian-taper screen would improve the contrast (but not the resolution) of fine detail in good seeing conditions, although with some loss of image brightness. To my knowledge, no one uses screens with these transmission characteristics.

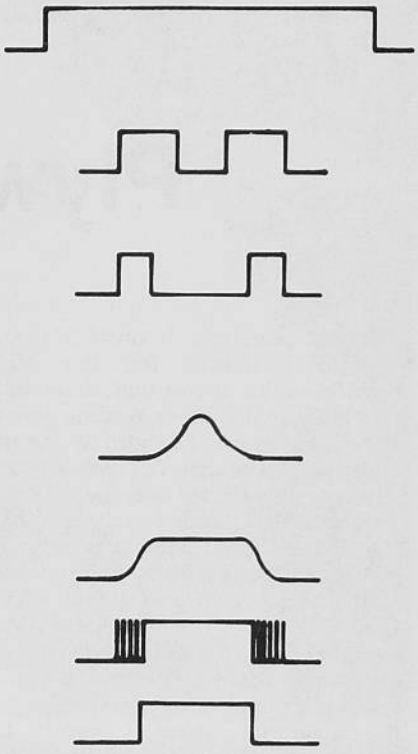
4) In obstructed systems, the larger the ratio of the obstruction to the full aperture, the smaller the diameter of the Airy disk (and the brighter the rings). An apodizing screen acting as a partially transmitting aperture stop in such a system might increase the resolution at the expense of the decreased contrast caused by the brighter fringes.

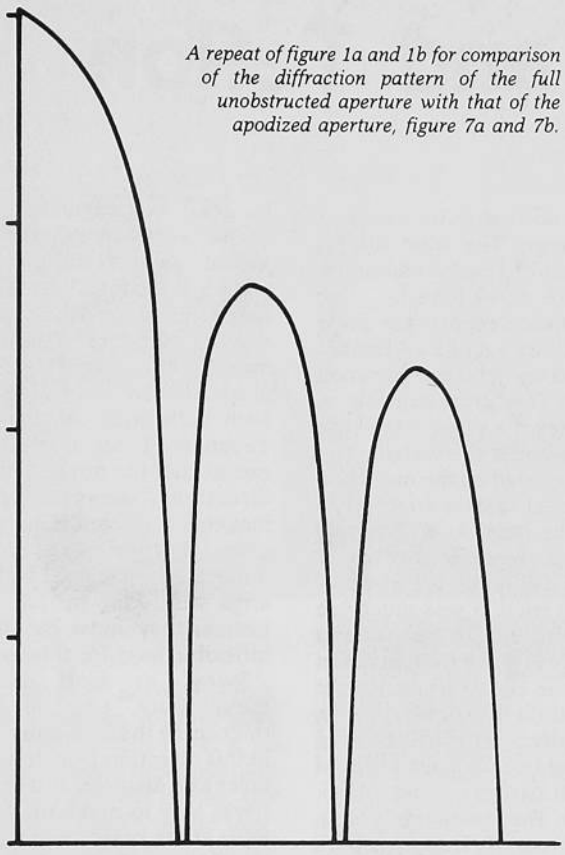
5) Observer bias may cause observers to look for and actually see more detail when they expect to see it with a screen in place. A test for this would involve observing planets with narrow-field eyepieces and a variety of screens, stops, and neutral density filters. An assistant would change the screens, stops, and filters in a random order, unbeknownst to the observer, who would record his impressions of the image. (The narrow-field eyepieces are necessary to keep telltale spectra out of the field of view.) The test should be run during nights of good and poor seeing, using a telescope with impeccable optics.

6) The eye-brain combination in observers plays a role by allowing more detail to be seen when the field-of-view contrast is reduced. R. Berry suggests that sophisticated image processing occurs in the eye and brain. Such effects cannot be factored into the calculations or into the impersonal response of photographic emulsions, but may be a real and important capability developed by nature for our ancestors on the African savannas, and now useful to skilled observers looking further afield.

Neither theoretical calculations, laboratory tests, nor field tests support the belief that apodizing screens improve the seeing. With a *properly designed* screen, however, the image contrast can be improved. Window screen apodizers, by reducing the glare of the image or reducing field of view contrast, make viewing of whatever detail is present in the image easier, but a neutral density filter used with the full







A repeat of figure 1a and 1b for comparison of the diffraction pattern of the full unobstructed aperture with that of the apodized aperture, figure 7a and 7b.

aperture will be more effective since the full resolving power of the telescope will be available, with reduced contrast. Proponents of these devices need to examine objectively the benefits they find with them and then explain the mechanism providing the benefits.

Early references to apodizing screens for astronomical use may be found in the Amateur Scientist or Amateur Astronomer sections of *Scientific American* for May 1951, August 1951, and June 1954.

I thank John Stacy for his assistance in doing the window screen apodizer FT. The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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Apodizing Screens and Aperture Stops

Clear Aperture	Screened Radius	Notes
5″	0″	Unmodified optical system
4.5″	Outer ¼″	Single layer window screen
3.5″	Outer ¾″	Single layer window screen
3.5″	Outer ¾″	Triple layer window screen: Outer ¼″ three layers, next ¼″ two layers, innermost ¼″ one layer
4.5″	Outer ¼″	Opaque stop
3.5″	Outer ¾″	Opaque stop

5″ aperture Schmidt-Cassegrain with 2″ central obstruction. Screen has 15.6 holes/inch by 19.4 holes/inch.

A Large Equatorial Mounting that employs Plywood and Teflon

Several years ago, I constructed an equatorial mount for my 10″ Newtonian, but it was underbuilt and extremely shaky. After reading about Dobsonian mounts, I decided to convert mine to a Dobsonian. For those of you who have never used one, the stability is remarkable. I decided on the spot that I would not build another equatorial mount until I could build one with this kind of stability. When I got my 17.5″ Coulter optics, I went ahead and mounted them Dobsonian style (except for a square plywood tube), so that I could use them while I was designing the equatorial mount. I wanted to incorporate the good features of the Dobsonian design into an equatorial mount — ease of construction, low cost, simplicity, transportability, and above all, stability — while keeping the weight and size down to reasonable proportions.

At first, the thing seemed impossible. For instance, gravity, which works for you in a Dobsonian, tends to work against you in an equatorial. After some thought, I decided that gravity contributed mostly to the Dobsonian's simplicity, while the stability was more a function of the size of the axis bearings.

I decided on a fork-type mounting because it is related to the Dobsonian, and because it is compact and requires little counterweighting.

The only type of polar axis that had the diameter I wanted and was practical in plywood was a conical axis similar to one I had seen in a Russell Porter drawing in *Amateur Telescope Making*. My version consists of a 32″ laminated plywood disk, 1½″ thick with eight reinforcing ribs of ¾″ plywood. A piece of 1½″ aluminun electrical conduit (like water pipe, except it's aluminum) runs the length of the polar axis and extends several inches out the south end. It is attached to the north disk by means of a 1½″ pipe flange. The front disk is edged with a strip of 1″ x ¼″ aluminum (larger hardware stores have it).

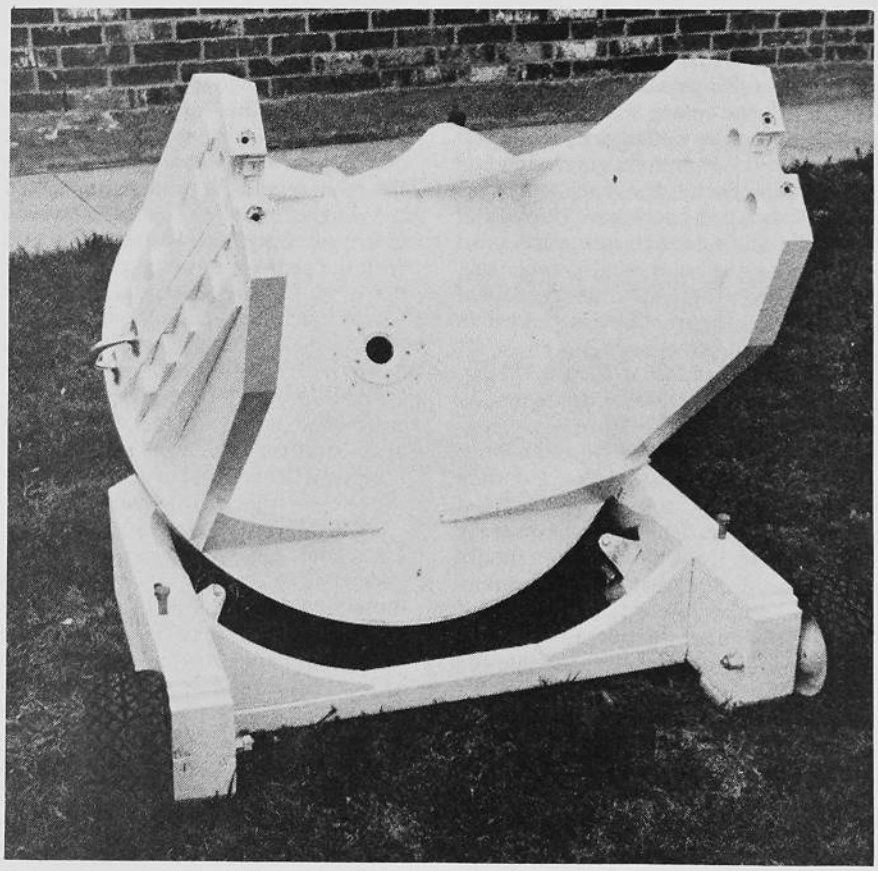
A U-shaped base supports the polar axis. This is built up out of 2 x 4 lumber on the sides and corners, and plywood in the back. The cross-bracing is important to keep the sides of the base from spreading under the weight. The polar axis is supported on the north end by two fixed steel casters attached to either side of the base. As an example of how design features evolve, I originally used Teflon pads instead of casters, but the friction was much too high. Then I tried one Teflon pad and one caster. Still too much friction. Then two hard rubber casters. The weight caused flat spots on the rubber wheels. I looked for casters with ball bearing wheels, but couldn't find any. I settled for simple steel casters — just wheel, axle, and frame. They work pretty well, particularly with Teflon washers between the wheel and frame. Automotive wheel bearings, or anything with bearings in it, would probably be better.

The south bearing is in two parts. Axial thrust is taken care of by a single Teflon pad attached to the base, and which bears on countertop material glued to the 6″ disk on the south end of the axis. Radial movement is prevented by three Teflon pads surrounding the 1½″ conduit. Since the center of gravity falls north of the casters, the main force on this bearing is upward, so the two fixed pads are above the axis, while the third is on a movable block below the axis. The block is tightened against the axis by means of two wing bolts and two tee-nuts. The U-shaped base sits on three feet, two on the north end and an adjustable one (like a refrigerator foot) centered on the south end. This foot is for polar axis alignment.

The weak link in the typical fork mount, aside from polar axis cross-section, is the fork arms. The ends of the fork arms can move in three different ways. I call these bounce, twist and sway. Bounce is movement perpendicular to both telescope axes, with both arms moving in the same direction. Twist is the same thing, except that the arms move in opposite directions. Sway is side to side movement, or parallel to the declination axis. Bounce and twist can be minimized by simply making the fork arms very wide in that direction. Of course, they must be attached to an inflexible base for this to be effective.

Sway, as well as the other movements, can be reduced by thickening the fork arms. I was limited in this direction by a desire to keep the polar axis diameter to a reasonable size. I was able to make the fork arms 20″ wide at the base, tapering to 15″ at the shoulder and 6″ at the end. The thickness is only 1½″, with tapering braces bringing the center of the base out to a 4″ thickness. I decided to deal with the sway component with the declination bearings. The simplest way to increase declination bearing size is to increase the size of the trunnion. However, this involves cutting large holes in the fork, thus weakening it, and I didn't want to do that. What I settled on was this: the trunnions are 1½″ conduit attached to the tube collar with pipe flanges. They are short, and flexure is minimal. Radial movement is prevented in a manner similar to that used at the south end of the polar axis, except that the fixed pads are on the fork arm, and the third pad is on a detachable end cap. Attached to each side of the collar is a 15″ disk of countertop material which bears on two Teflon pads inside the fork arm perhaps

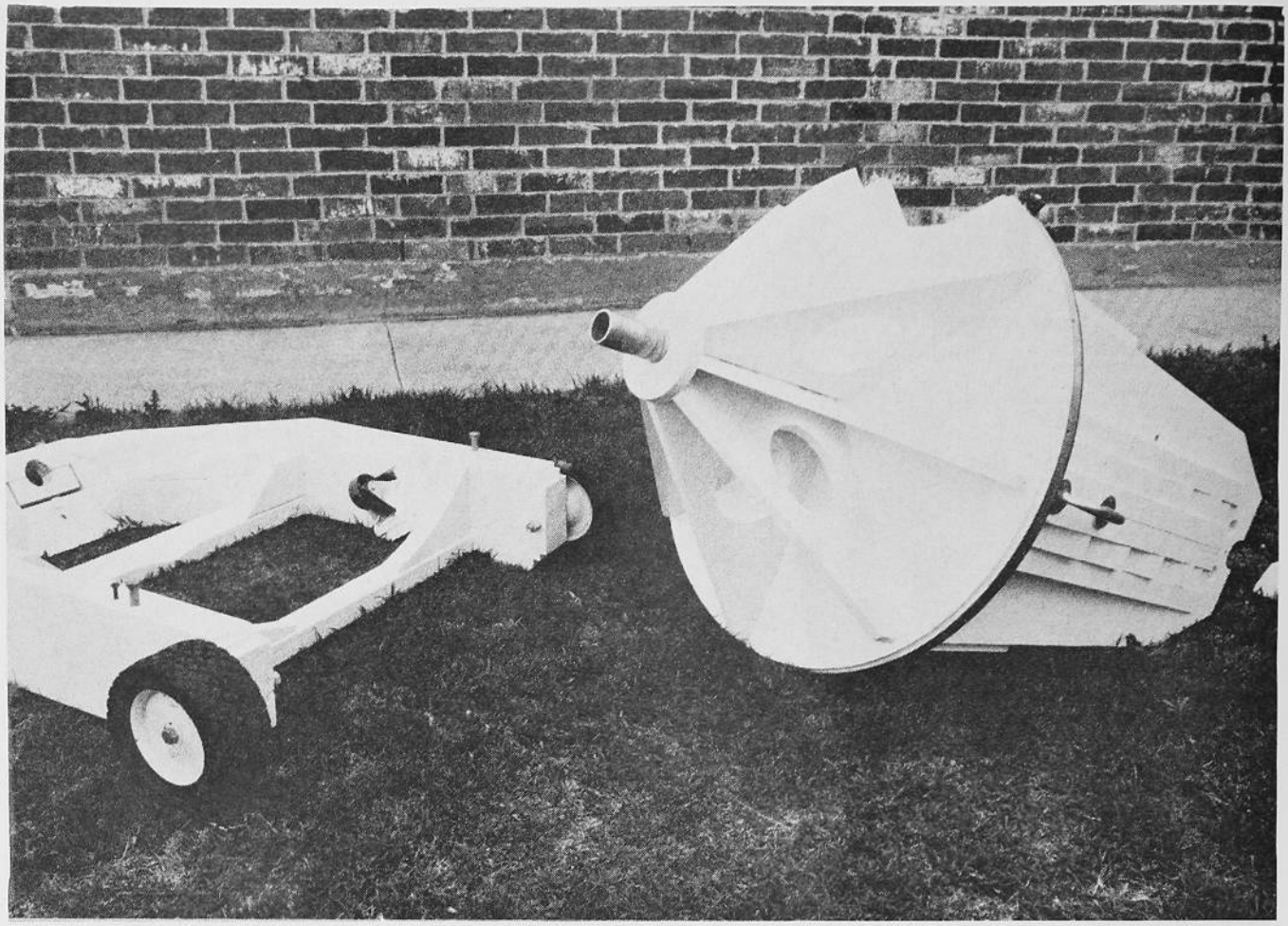
Above: D. Eric Allen and his 17″ equatorial



6″ apart, and about 7″ nearer the fork base than the trunnions. All four pads are in contact with the tube collar at all times. Since the fork and tube collar are touching in four different places, the tube collar is held rigidly in the fork, thus preventing any twist strain on the trunnions while slewing in right ascension. This eliminates backlash. When the declination axis is pointed to the meridian, the weight of the tube assembly is borne by the pads, which are nearer the base of the fork than the trunnion. This effectively shortens the fork arms, which minimizes both sway and twists.

The bearing surface could be extended to the full size of the tube collar or even beyond, with proper bracing, making the effective fork length extremely short. I was limited to 15″, having previously cut holes in the collar for weight reduction. However, 15″ bearings give adequate stability, so enlarging them in this particular mount would be a waste of effort. The large declination bearings also bring the declination axis friction more in line with the friction of the polar axis.

The tube collar is essentially a box



made of ¾" plywood, 22½" square by 25½" long, with a hole cut in each end for the tube assembly. The tube assembly can rotate 360° in it. This is accomplished by Teflon pads bearing on two 1" x ¼" aluminum rings attached to the tube. Each side of each end of the collar has a pad bearing on the face of the tube ring, and each corner has a pad bearing on the outer edge of each ring, thus preventing all but rotational movement. The front face is removable for occasional disassembly.

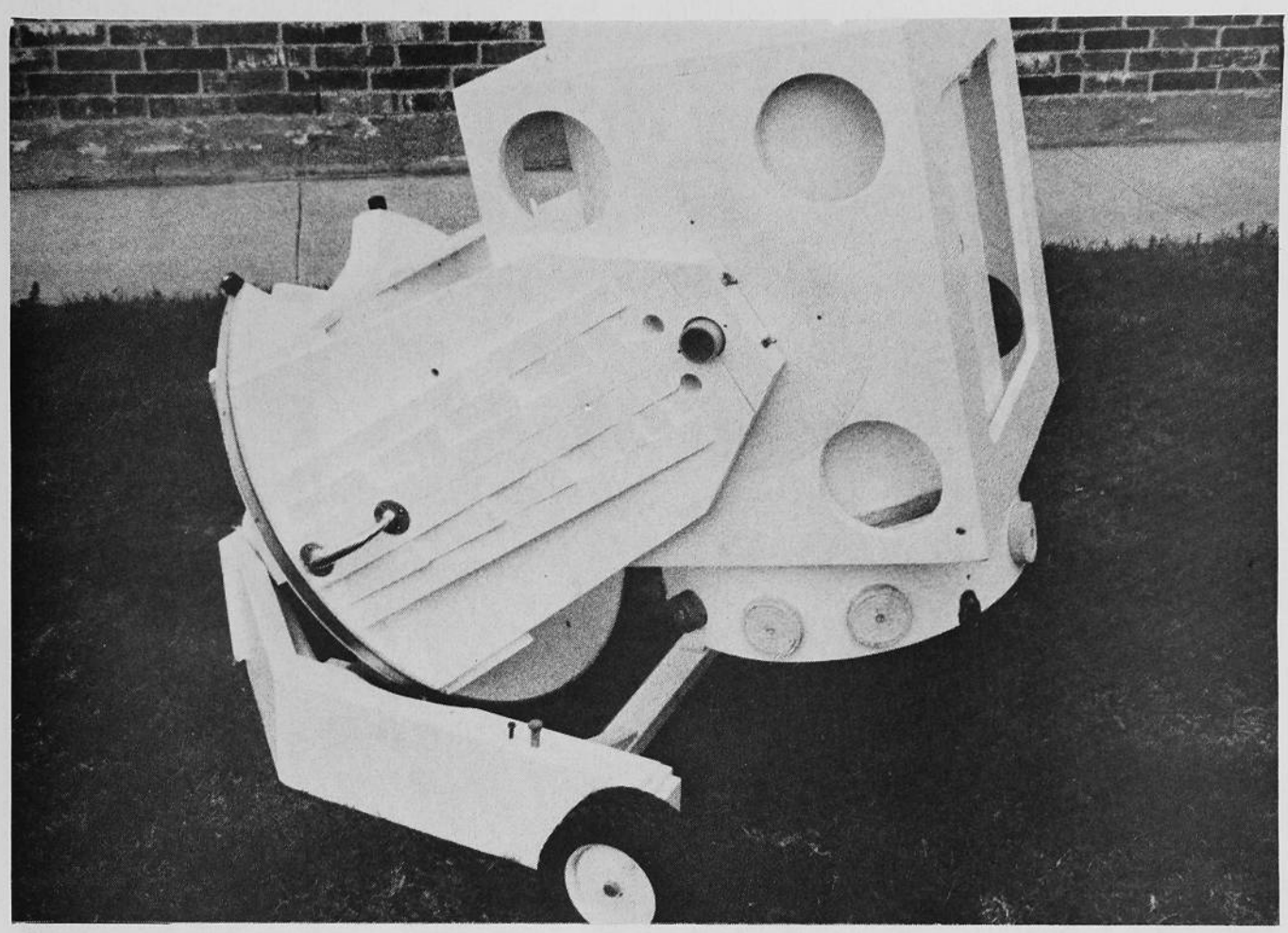
The tube assembly is 19½" I.D., and is made of 3/8" plywood. The inspiration for this and for the aluminum rings comes from *Newtonian Notes* by Peter Francis. I made the tube 12-sided, then belt-sanded the corners to make it 24-sided. By this time it was so nearly round that I just belt-sanded it round! The tube was a great deal of trouble, even with a borrowed table saw, and if I had it to do over, I probably wouldn't. In addition to the two rings inside the collar, a similar ring at the front of the tube supports the spider. Without the rings, the tube would not be rigid enough.

The tube breaks down into three sections. This is a carry-over from the original square tube, which was inspired by Richard Berry's 20" (TM#7). The front section carries the spider and secondary holder, the focuser and the finder. The center section is basically empty tube, but it carries lead weights to counterbalance the focuser and the finder. I arranged the weights so that the center of gravity of focuser, finder and weights coincides with the center of gravity of the rest of the tube. I'm not an engineer, so this was as much trial and error as anything. There are easier ways, but this required the least amount of weight. The weights were made by melting down automobile wheel weights, pouring the lead into cat food cans, and then removing the cans. I curved them to fit the tube by placing them on the open jaws of the vice and beating them with a hammer. Lead is very cooperative.

The third section of the tube is essentially the mirror cell glued into the last few inches of tube. The cell is made up of laminated rings of plywood. It adds structural strength to the tube. The mirror sits on a 9-point flotation similar to that described for a Dobsonian — mostly plywood. The base of the cell is ¾" plywood. The mirror is supported radially by six equally spaced bolts through the cell, with a Teflon button between each bolt and the mirror. The mirror is free to move radially within narrow limits and sits on whichever one or two buttons happen to be under it at the time.

Joints between sections of tube have 2" strips of masonite attached inside the rim of the center and rear sections. These form a ½" lip which extends into the adjoining section when assembled. This keeps the sections aligned, and also strengthens the tube at the joint somewhat. These joints are held together with loop fasteners which are installed in such a way that the front and rear sections, containing all the optical parts, can be snapped together and carried up front with me during transport.

The spider and secondary holder are a new design. They consist of four vanes of galvanized sheet metal attached to a center of 1½" aluminum conduit. Outside this, a circular block of aluminum about 3" in diameter and ¾" thick attaches directly to the vanes with angle braces. The mirror side is threaded externally for a piece of 3" aluminum tube which carries the 4¼" minor-axis secondary mirror. The mirror is glued to the angle-cut face of the 3" tube with silicone-type glue and

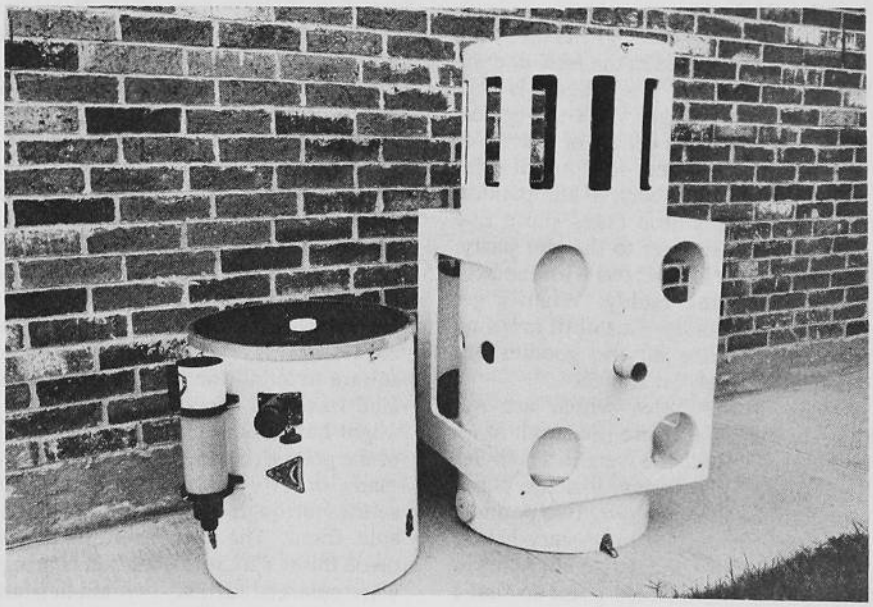


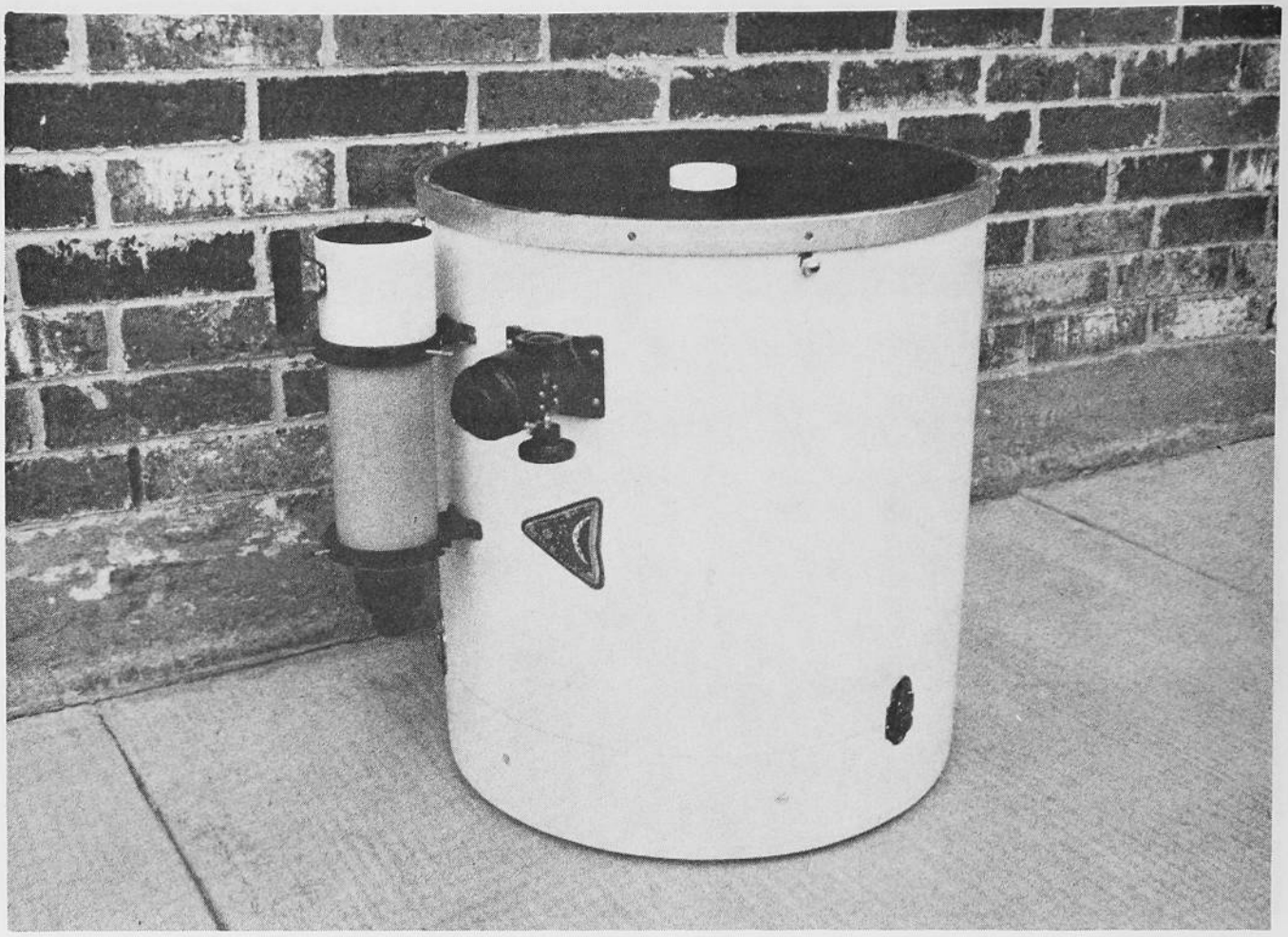
is offset. The secondary holder has no adjustments beyond what is necessary to install it and is made to be permanently collimated. It is three weeks old at this writing, so it is too early to tell if it will stay collimated. It is made from what used to be my homemade finder.

My present finder is an 11 x 76. A couple of years ago Eddie Keeton, an observing buddy, gave me a surplus Aero Tessar telephoto lens with a broken front element. I bought a Jaegers plano-convex lens of slightly larger diameter and, as near as I could determine, identical focal length to the broken element. Maintaining more or less the original spacing, I stuck the optics into a PVC tube and added an eyepiece. I probably wouldn't take great pictures with it — nobody's *that* lucky — but it makes a great finder.

The wheels on the base are paired 8″ lawn mower wheels. They are adequate for the approximately 245 pounds of the telescope and mount, although the axles (½″ bolts) are set in wood and may eventually have to be reset in metal. The wheels do not touch the ground until the rear of the base is lifted. I can move the telescope short distances by simply picking up on the south end of the polar axis and rolling it. For longer distances, the tube can be locked in the fork and the polar axis locked in the base by means of three bolts which I keep stowed in the base. The whole works can then be rolled around like a refrigerator cart. Either method is easy for the average person to handle, but it rolls well only on pavement or hard-packed dirt. The overall center of gravity is right behind the front feet.

I keep the telescope assembled in my garage. When I go to a star party, this is the procedure: I unfasten the rear section and place it on the tailgate of my pickup. I unfasten the front section and refasten it to the rear section. I take this combination and put it in the passenger





side of the pickup. I take the caps off the fork arms and call my wife to help. In a pinch, I can do the job myself, but it is much easier with two people. The center section of the tube (with collar) is removed and set aside. The fork/polar axis is removed (after loosening the two wingbolts) and set aside. The base is rolled or carried to the pickup and put in the bed. The fork/polar axis is reinstalled in the base. The center tube section is reinstalled in the fork, and the caps put back on. The tailgate is shut and I'm ready to go. With the optical ends removed, the center of gravity of the remainder is very low, and it rides very nicely in the back of the pickup. The whole operation takes about five minutes. When I get to the star party, the procedure is reversed with the help of an observing buddy. When I get home, I frequently wait until morning to unload, since all the goodies are locked up safely in the cab.

Most of the holes which are not readily identifiable are the result of an attempt to reduce the weight. The holes in the tube just forward of the collar only reduce the weight by two pounds, but have turned out to be very handy for rotating the tube. I also cut holes in the tube at the balance point so that I can sight through the hollow polar axis during polar alignment. I can sight through the declination axis when the time comes to critically square it with the polar axis. At this writing, I have not installed drive or setting circles. When I do drive it, I will probably use a worm and wheel on one of the casters, adjusting the caster diameter to get the exact rate.

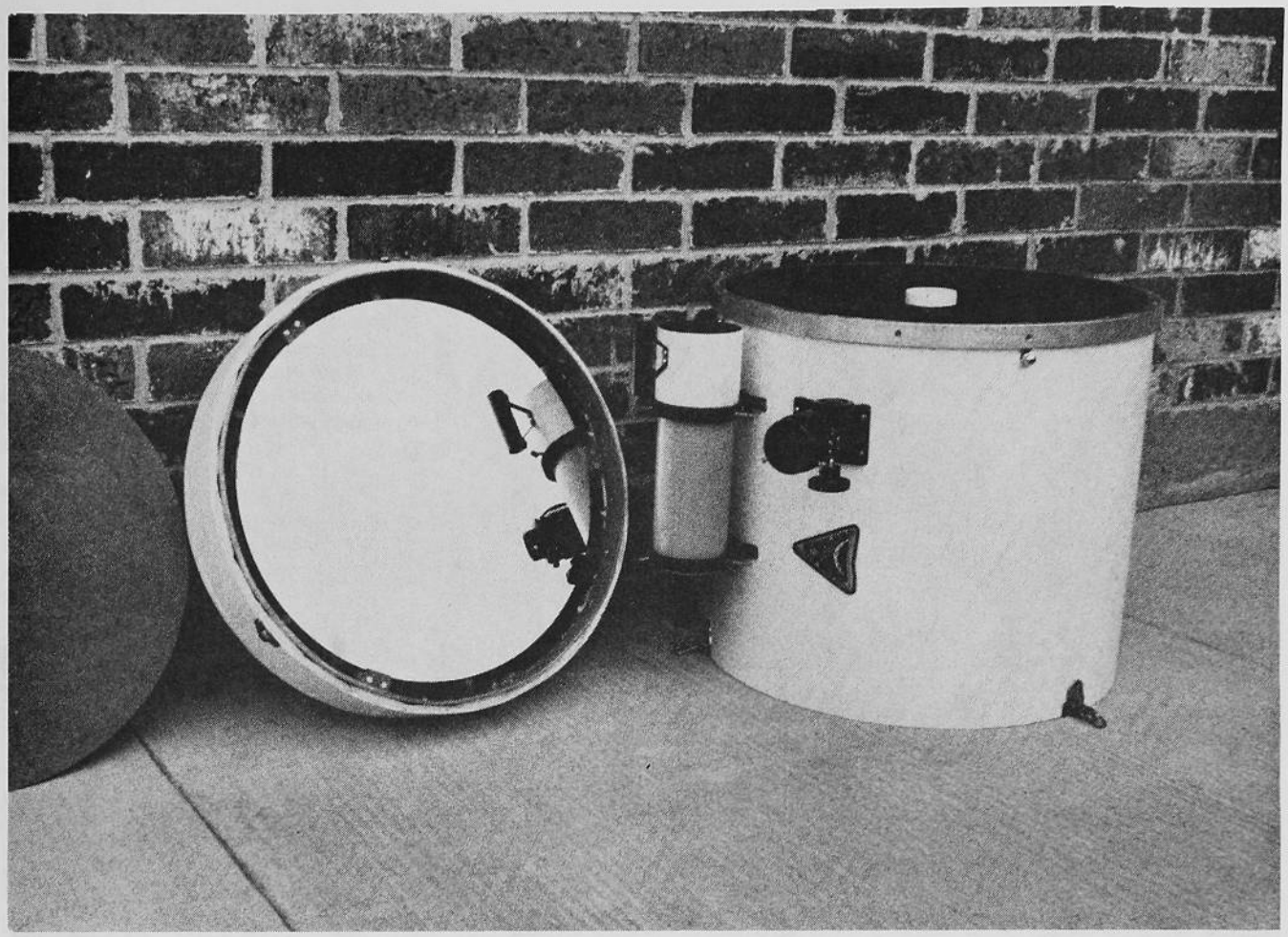
I'm afraid there aren't any scale drawings. I used the design-as-you-go method, making each piece to fit the previous piece. It generally works out all right, but there are times when it would be nice to have a master plan. Rough sketches don't always work out.

There are several things I would probably change if I were starting over, and several other things which could be done differently by someone contemplating building a similar mount. The corners of the base could be made square to avoid the compound angles. Had I not had access to a table saw, I might have done this myself. The ribs of the polar axis cone could probably be made of ½" plywood, although the screws through the polar disk might split them. The disk itself might be made thinner if the declination bearings were enlarged further. I would hesitate to lighten the fork arms unless very large declination bearings were used. The sides of the tube collar should probably remain at ¾", but the rest of the collar could probably be ½". The tube could be Sonotube and the reinforcing rings plywood. The rotating tube feature could be simplified or eliminated altogether if you were willing to put up with awkward eyepiece positions.

Further changes and improvements could be made — in fact, I have a few in the planning stage. One recent modification was to notch the polar disk for better access to the southern sky. I also added rubber bumpers for the tube to stop against; more bumpers serve as stops for polar axis rotation. At my latitude of 35.5° (Oklahoma City), I can get within 8° of the southern horizon.

The following are specific data pertaining to the mount:

Weight:	
Mirror and cell	37 lbs.
Front section	20 lbs.
Center section	61 lbs.
Fork/polar axis	81 lbs.
Base	46 lbs.
Total weight	245 lbs.



Force necessary to move:

Right ascension	5 lbs.
Declination	2 lbs.
Tube rotation	20 lbs. (approx.)

For anyone wishing to build a similar mount, the construction is only slightly more complicated than a Dobsonian. The cost is higher, but again, only slightly. I have lost track of the time and money spent, what with reusing old material, using leftovers from this on other projects, and so forth. A table saw is helpful, but not essential, except perhaps for the tube. I used a few second-hand machined parts, but machining is not necessary.

The total weight of the telescope is comparable to the Dobsonian. It takes up a little more space, but not much. The stability is comparable to the Dobsonian. It moves very smoothly, but like many equatorials, it is a bit awkward near the pole.

I bought the optics from Coulter Optical Co., and they are excellent, even by Coulter's high standards. I had a chance to check it out thoroughly at the '84 Texas Star Party. The light gathering is great, but no different than any other slightly dusty 17½" telescope. What surprised several people was the resolving power. We were getting some excellent planetary images early Thursday night. This really shouldn't be surprising, since resolving power, like light gathering, is a function of aperture. However, large, fast optics don't automatically provide high resolution. Assuming quality optics, you still need seeing good enough to take advantage of the aperture, and, at f/4.5, you need near-perfect collimation, including, if necessary, alignment of the focuser (see TM#22). I had fine-tuned my own collimation Thursday afternoon. I'm shooting for permanent collimation, but haven't quite perfected it. I didn't notice any performance problems with the optical mountings. Apparently, radial support of a 1:13 thickness ratio mirror is not critical, as long as it doesn't bind. The glued-on secondary was no problem. I have noticed more recently that with a brisk wind blowing into the mouth of the tube, I get a high-frequency vibration of the spider vanes, and thus of the image. The vanes are thin, made of whatever gauge sheet metal they use for residential ductwork (perhaps 0.020" or 0.025"), and should be heavier.

The mount was a lot of fun to build, and is even more fun to use. It has turned out all I intended it to be: inexpensive, easy to make, transportable, stable, and, of course, equatorial. I don't know when I will get around to adding a drive to it — but whatever drive I add must be one that will not interfere with its already convenient operation. I like it just as it is.

I have gotten inspiration from many sources, but there are two I would particularly like to mention: Russell Porter, for the conic polar axis and his insistence on mount stability; and John Dobson, for the revolutionary alt-azimuth mount which brought telescope stability within the reach of the average hobbyist, and upon which my own mount is based.

I would like to encourage other amateurs to experiment with the design. I know it can be improved. Meanwhile, I was pleased and honored to have received a design award for this telescope at the '84 Texas Star Party. To those responsible, I thank you. Were telescope building not already a compulsion for me, this award would certainly motivate me for many years.

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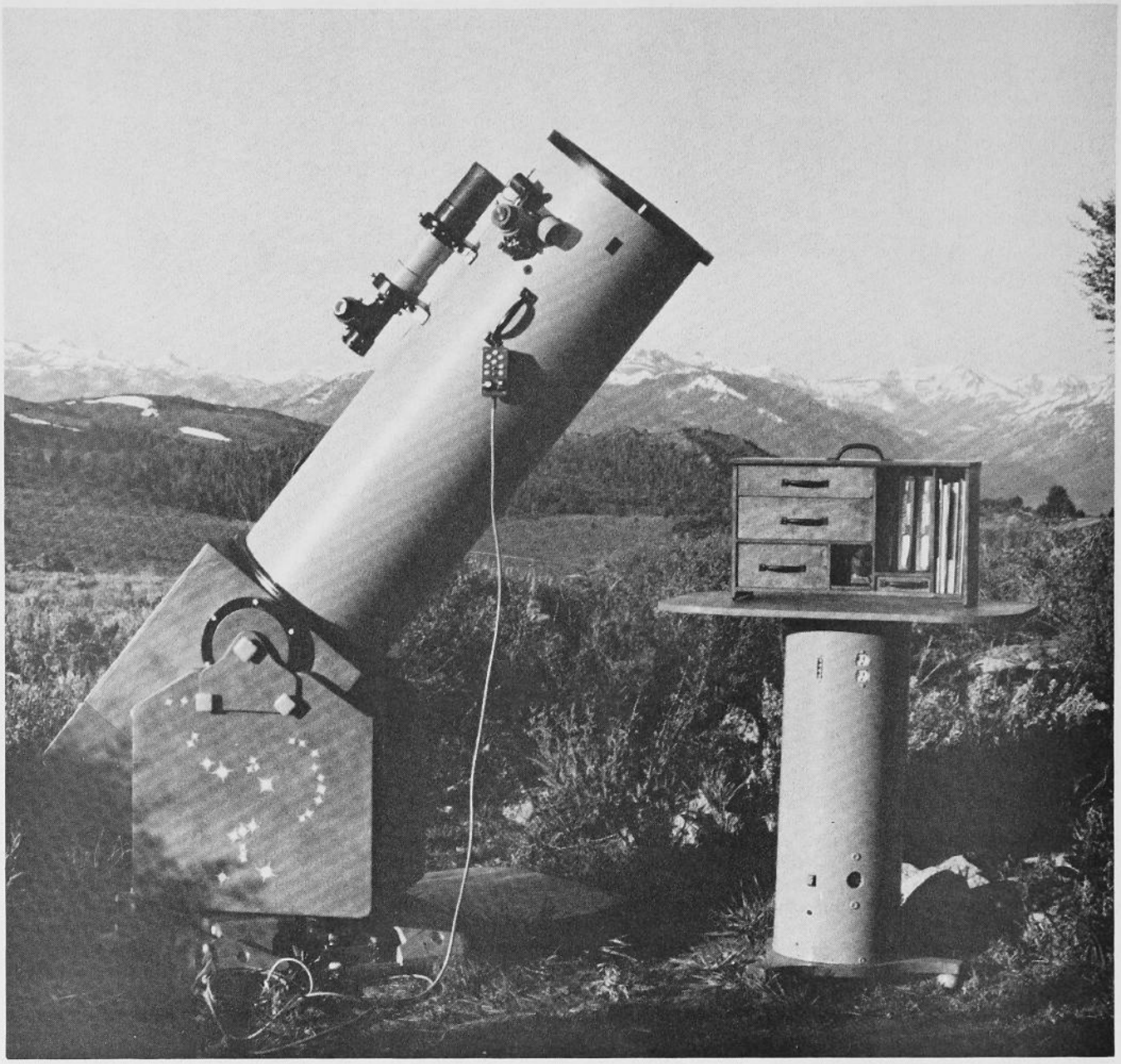


A 16″ Dobsonian on a Pursell Platform

The equatorial platform for my 16″ f/5 Dobsonian was directly inspired by two articles in TM#19. First, Wally Pursell's cogent vector analysis led me away from the classical Poncet mount with its inclined plane. As Pursell points out, rotating the contact surface 90°, *a la* Palomar's horseshoe mount, makes for a much more stable configuration for latitudes below 45°. By the way, in analyzing Pursell's article, I feel he is incorrect when he states (TM#19, page 45) that the pivot, the driving point, and the bottom of the convex arc (of the "horseshoe") all must lie on the same baseline. For stability you want to put the curved "feet" carrying the remnants of the horseshoe arc as far apart as possible. This can necessitate the bottom of the arc being considerably below the line formed by the pivot point and driving point. No matter. The IMPORTANT thing is that a circle defined by the curve on the feet be pierced perpendicularly through the center by an imaginary extension of the stubby polar axis (which I use instead of Pursell's south pivot point).

Inspiration for the drive components of my platform came from Tom Martinez's "state of the art" Poncet platform, also described in TM#19. In particular, I liked his ingenious method of converting the linear motion supplied by the threaded rod into the circular motion needed to drive the platform. This is accomplished with a spherical rod end bearing screwed into the driven nut and attached at the ball end to a small slide bearing mechanism which is in turn fixed to the telescope platform.

Also, like Mr. Martinez, I use two motors, one to drive the platform at the tracking rate and one for fast rewind. However, my method of coupling both motors to a differential allows added versatility. With my push button box, I can use the fast rewind motor as a reversing slew motor to center objects in the field of view or for sweeping an area in r.a. A switch on the control box

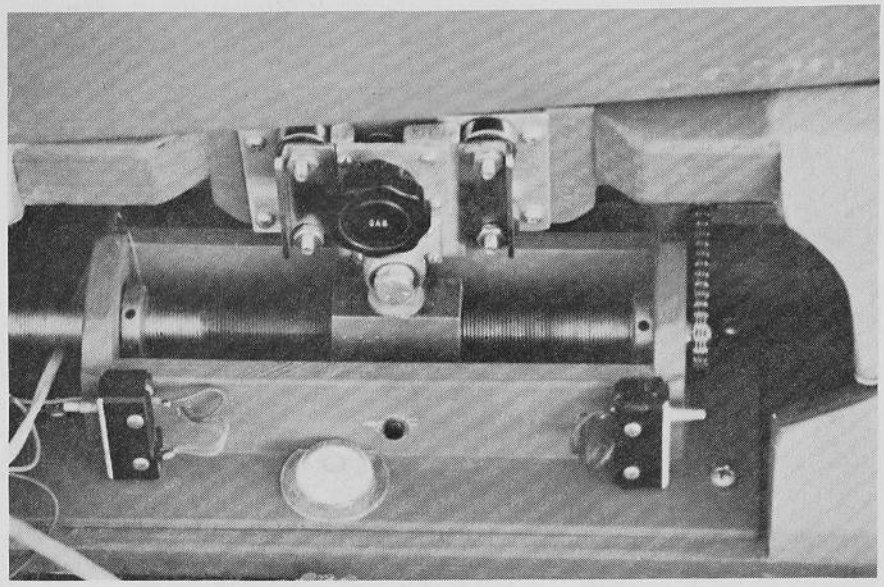
gives me a fast or slow slew rate. A similar switch also varies the speed of the motor on my Crawford focuser. My power source for all the motors is a bank of three 6-volt Gel-Cell rechargeable batteries. These are hooked in series, giving 6, 12, or 18 volts for the control box, so I can vary the speed of the DC motors by sending different voltages to them. The speed of the DC tracking motor is continuously variable by means of a small DC voltage regulating circuit obtained from Radio Shack. I do have plans to convert over to an AC synchronous motor and inverter for an even more consistent tracking rate.

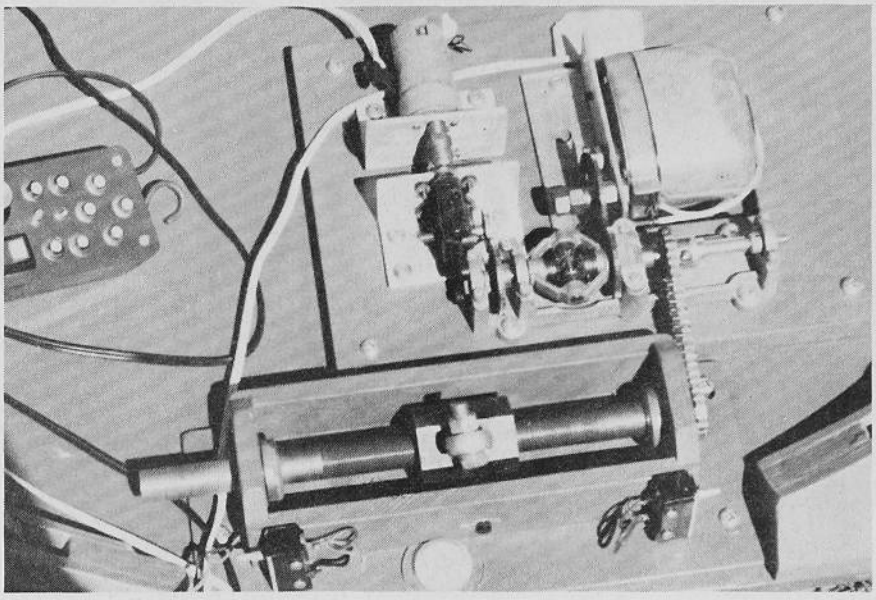
The mount tracks for about an hour before it needs resetting. Cut-off switches are tripped by either "foot" on the platform. To reset, I simply push the black button on the box carrying the threaded rod — overriding the cut-off switch — and then push the proper button on the control box. Rewind time of the brass nut is about 30 seconds at high speed.

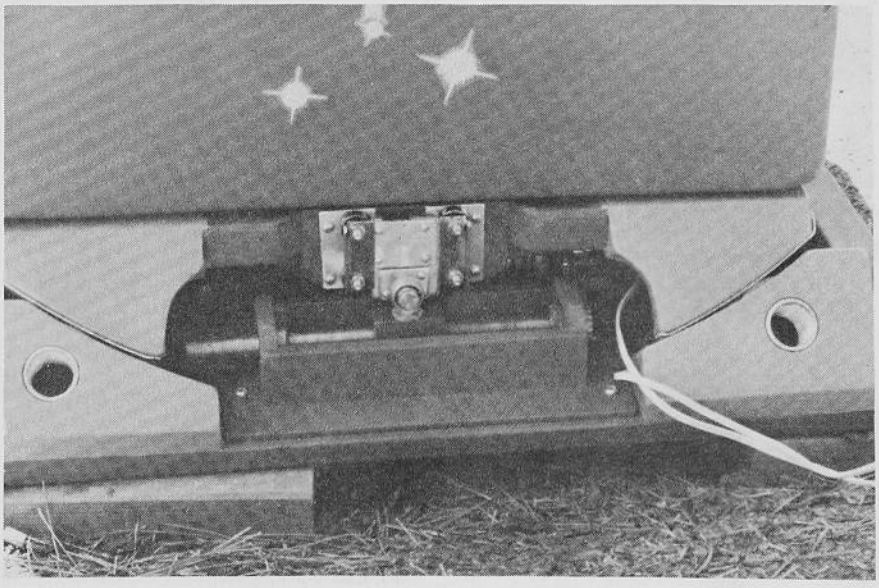
A few comments on mechanical stability are in order. First, I recommend a "square" format for the platform and its base instead of Martinez's "triangular" structure. In particular, a properly leveled 4-point ground contact seems beneficial. For a heavy telescope, it is essential the platform run on ball bearings. The two aluminum-shod north feet of my platform rest on the outside surfaces of 3" ball bearings mounted in plywood frames attached to the lower base. The south pivot bearing is a self-aligning type which accepts the stubby polar shaft of the platform.

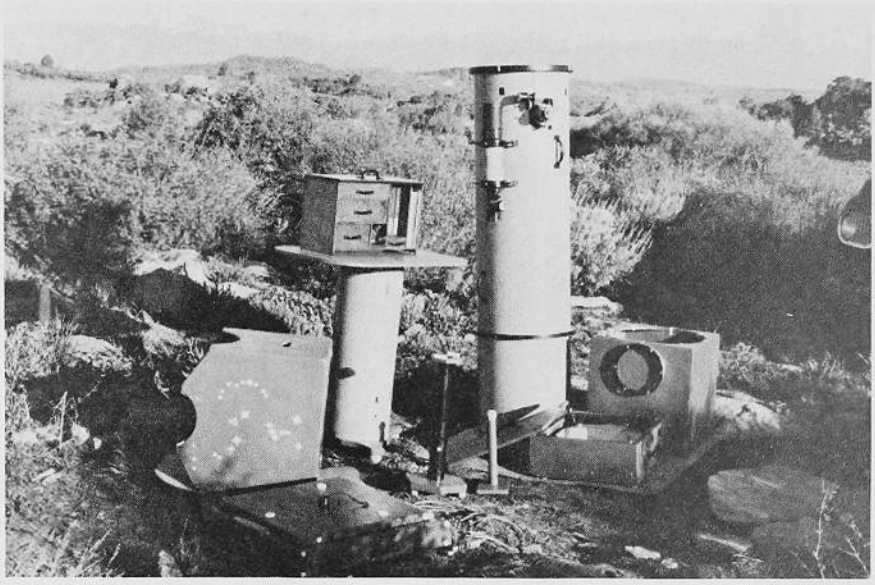
Use of a stout threaded rod is recommended. Mine is ¾" x 16 TPI rod mounted in small ball bearings. It is turned by a chain and sprocket driven by the output shaft of the differential. I had a local machinist make the large hexagonal brass nut which moves on the threaded rod. I took up residual play between the nut and rod by cutting the nut longitudinally along one side, drilling and tapping holes on the cut side, and then tightening the nut against the rod with machine screws.

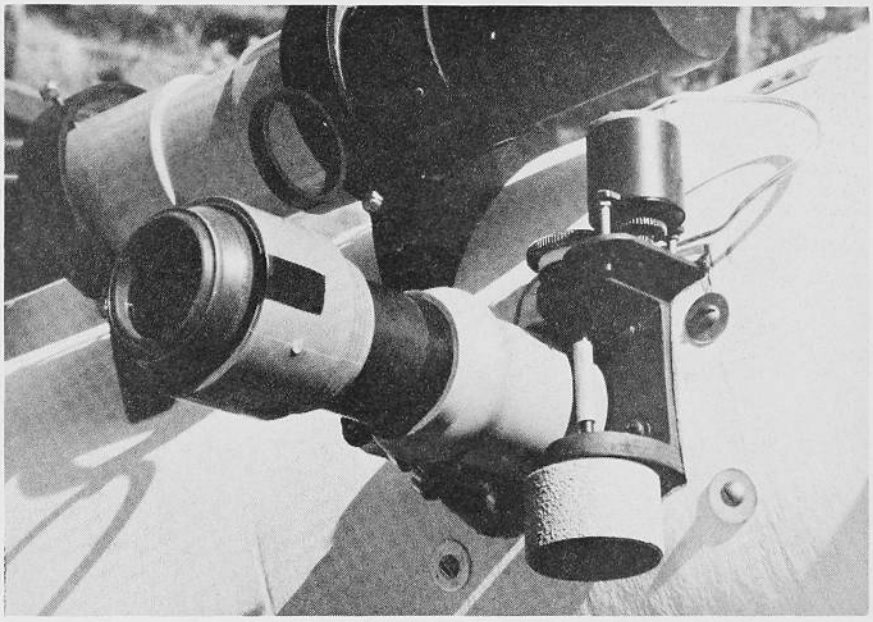
Some features of the telescope proper might be of interest to fellow TMs. I incorporated an adjustable friction mechanism into the altitude axis of the Dobsonian mount. A bolt, carrying a nut threaded onto it, passes through one side of the tube box, through the center point of the aluminum trunnion ring carrying a Formica clad plywood disk, and through another plywood cutout which in turn is fixed to the rocker box with two removeable bolts — the lower knobs visible in the pictures. I adjust the

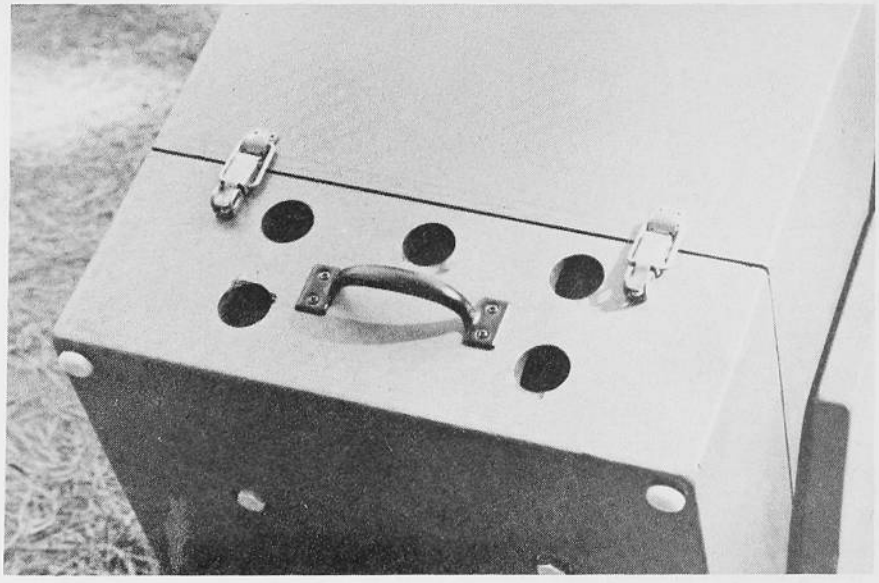












friction by turning the top knob, which tightens the nut. This squeezes the Formica disk against three Teflon pads mounted to the outside of the tube box.

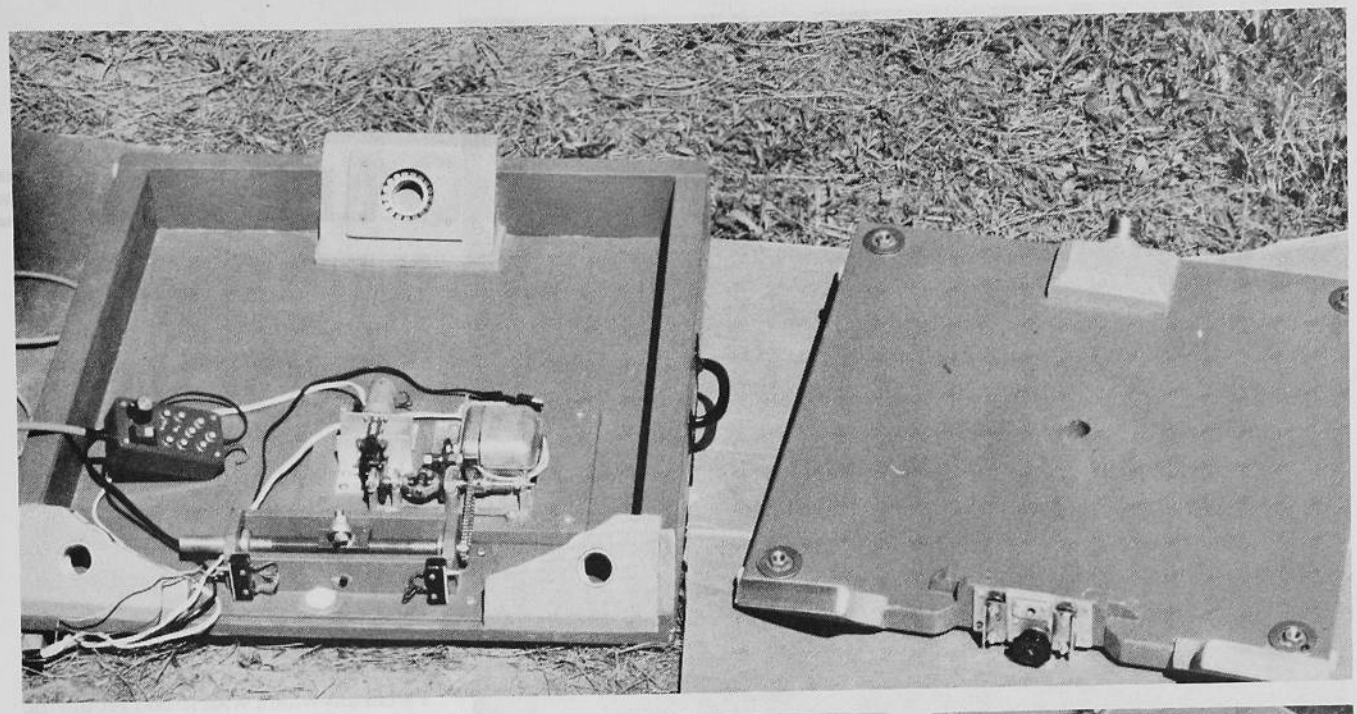
The 16″ f/5 mirror was figured by Enterprise Optics. Numerous favorable comments about its image made by many trained observers attest to the mirror's fine figure. I have it mounted in a 9-point flotation cell. Edge support is provided by a 180° sling. The entire mirror cell is simply snapped onto the lower end of the tube box with four trunk latches. It is thus easily removeable for transportation. Four dowel pins at the corners of the top face of the mirror cell slide into holes in the tube box, assuring a consistent fit between the two components.

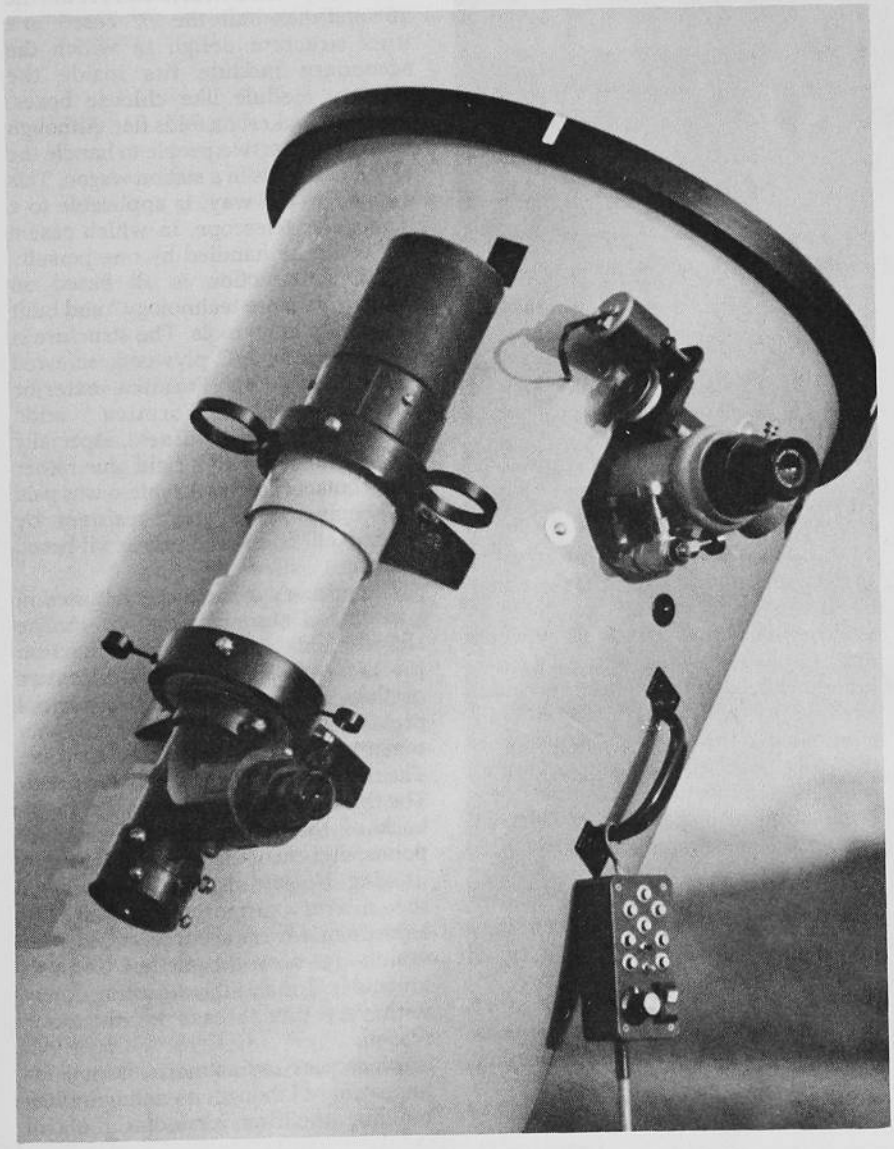
The 18″ I.D. sonotube slides into the tube box. Teflon pads at the top and bottom ends of the box allow the tube to be rotated in order to obtain the most convenient eyepiece position.

I constructed a Crayford focuser from plumbing valves, PVC tubing, plywood, and ball bearings. Focusing adjustment can be made either with the large hand knob or via push buttons on the control box. Friction clutching of the motor mechanism is achieved by squeezing the main drive gear (attached to the pinion) between Teflon pads. Either manually or electrically, focusing is very smooth and vibration-free.

At Riverside many people asked me, "What kind of eyepiece is that?" The object of their inquiry was my SWAC — my Secret Weapon Against Coma. I team up a 38mm giant surplus Erfle with a 2″ diameter Barlow obtained from University Optics. The equivalent focal length comes to about 17mm and yields 125x. Good eye relief combined with a very wide apparent field yields a true "porthole" effect. Star images are round almost to the edge of the ½° field, and the sky background is quite dark — useful for finding those fainter galaxies or the subtle detail in the brighter ones.

Providing a means of accurately aiming a large telescope at faint deep-sky objects is of great importance. Otherwise frustration can quickly ruin an observing session. Setting circles are one answer — with computer conversion of altitude and azimuth to r.a. and dec. if the mount is a standard Dobsonian. However, a Dob on a driven platform presented problems with setting circles I have never seen addressed — nor did I intend to try! So, being an avid starhopper myself, I provided the 16″ with a 3″ finder working at 18x. Many of the smaller and/or fainter deep-sky objects can be directly seen in such a finder, making acquisition in the main telescope field easy. But how do you initially get an





object into the field of this 18x right angle finder? Well, two sets of rings mounted on the finder brackets give me convenient peep-sights for initial aiming. These rings, along with the rest of the finder, are constructed out of plastic plumbing tubing. The elliptical mirror in the "sanitary tee" at the eyepiece end slips out the back, allowing either straight-through visual viewing or photography with the finder.

All in all the telescope is a fine performer. It comes apart easily into manageable parts for transportation in my van. The equatorial platform is proving to be a great convenience — both for the astronomy classes I teach and for the serious high-power observing I do myself. Lastly, the glow-in-the-dark star decals on the rocker box allow me to observe Orion on warm summer evenings!

Tom Osypowski
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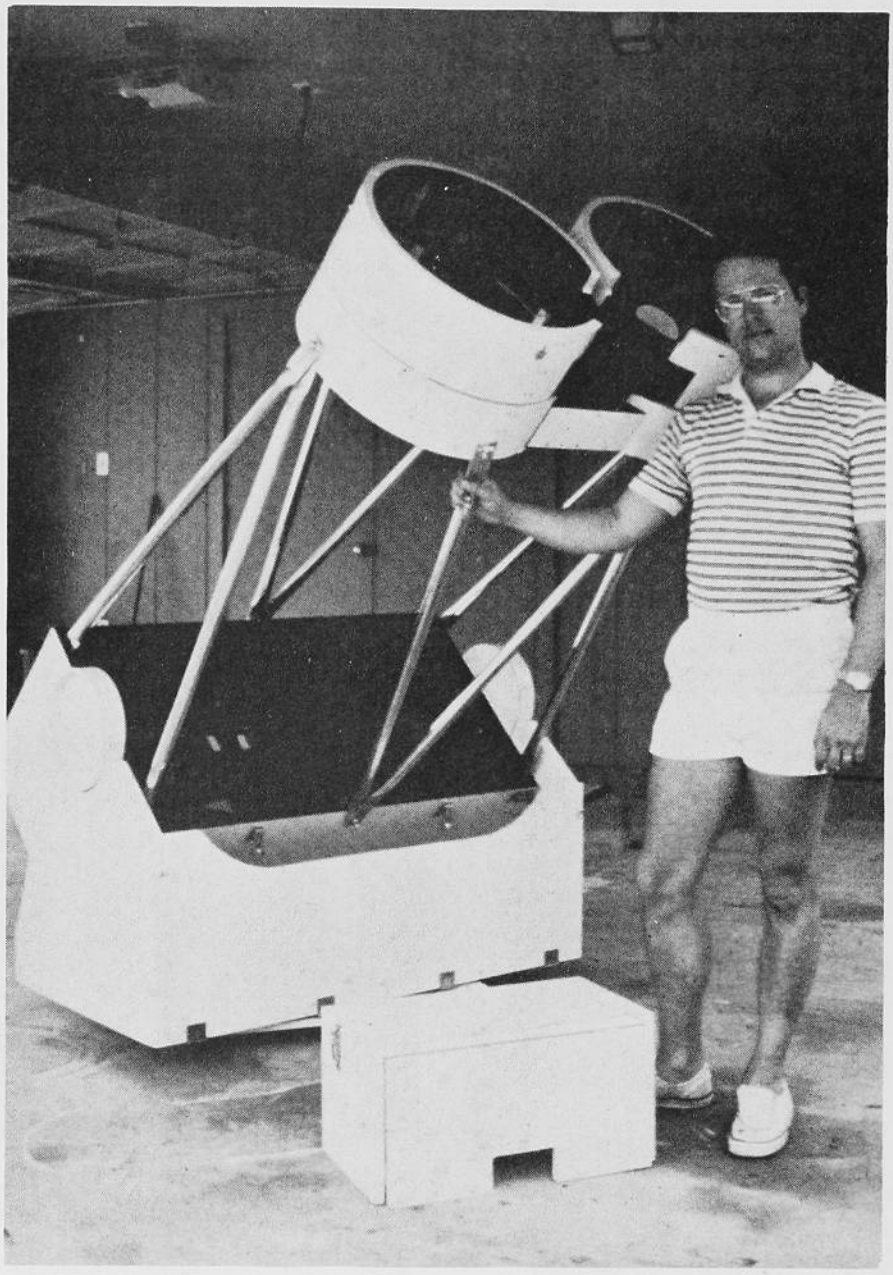
LEE CAIN'S



Last year I built an experimental 13″ binocular — the one I described in TM#20. It was based on the idea that when observing faint images (such as galaxies) or fine resolution images (such as globular clusters) the brain, when supplied with information from both eyes, can create an apparently brighter and higher resolution "brain image." And the "brain image" is what we actually see. Since then many people who've looked through the 13″ attest that this is so.

The binocular enhances brightness, resolution, and color. The image seems more "real," apparently because the brain more readily believes what it sees through both eyes. In a monocular instrument, faint and unfamiliar celestial images must compete for the brain's attention against visual clutter in the unused eye — such as retinal blood vessels and afterimages. But with a binocular, the identical celestial images in both eyes reinforce each other, while defects of the individual eyes can be differentiated and eliminated by the brain. Then there's the "3-D" effect. Most people claim to see it in the binocular. Of course there is no observable parallax of celestial objects, but two things contribute to the effect. First, the image is perceived at a definite distance from the observer. This distance is set when collimating, and I put it at 5-10 feet. This, in turn, gives the image a real perceived size. An additional advantage of a binocular is that you can put twice as much glass area to work at a given magnification without exceeding the eye's limiting exit pupil diameter.

Though it worked well, the first 13″ was difficult to field-collimate — and I had to borrow a pickup truck every time I went anywhere with it. So I rebuilt the 13″ and then built the 17″ based on a truss structure design in which the secondary module fits inside the primary module like chinese boxes. Also, the rockerbox folds flat. Although it takes at least two people to handle the 17″, it easily fits in a station wagon. This design, by the way, is applicable to a monocular telescope, in which case a 17″ could be handled by one person.

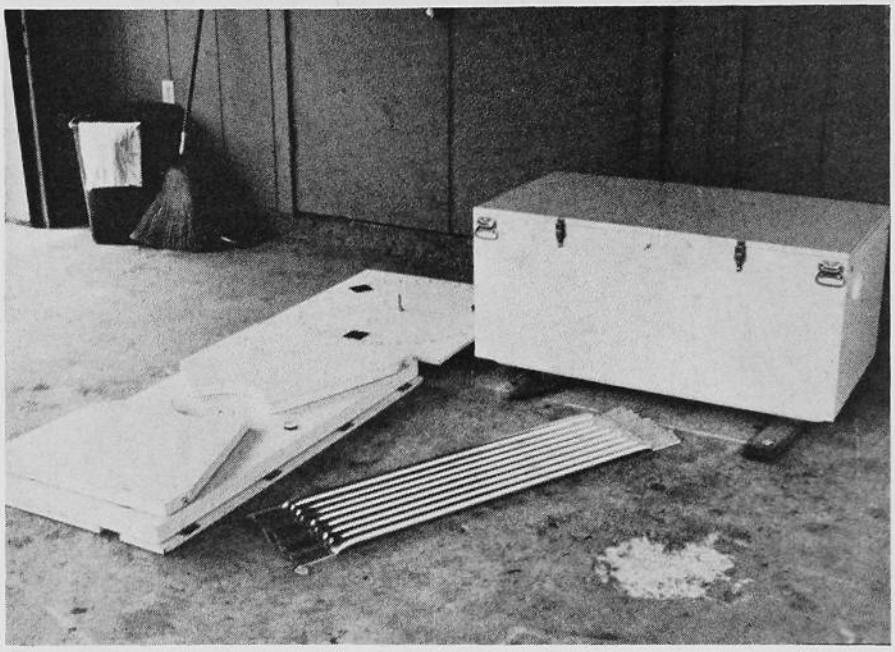
The construction is all based on "hardware store technology" and built using only hand tools. The structure is exterior grade A/C plywood, screwed and glued with Formica exterior surfaces. The Formica adds considerably to the stiffness, especially when attached with a rigid glue rather than contact cement. Attention was paid to keeping it all water-resistant by sealing all holes and using oil-based paints.

The primary mirrors are mounted in a modified Dobsonian sling system. The slings are double jointed and hung from pivots slightly aft of the mirrors' centers of thickness; this keeps the mirrors pressing against the flotation pads even when observing at very low altitude. The mirrors are permanently mounted. The three flotation pads are glued to the back of the mirror at three contact points, and each mirror is spot-glued to its sling. No soft materials are used on the mirror supports so that the adjustments are as accurate as possible, which is very important with a binocular. I made the adjusting screw with very fine threads for the same reason.

Interocular adjustment is not as important as I thought it would be when building the first binocular. Lots of

TRANS PORTABLE DOBSONIAN BINOCULAR

Assembling the binocular:
1. *All the parts spread out of the floor. The rocker is knocked down and the upper end and mirrors stored in the closed tube box.*
2. *Inside the box, the upper end nestles above the primary mirrors.*



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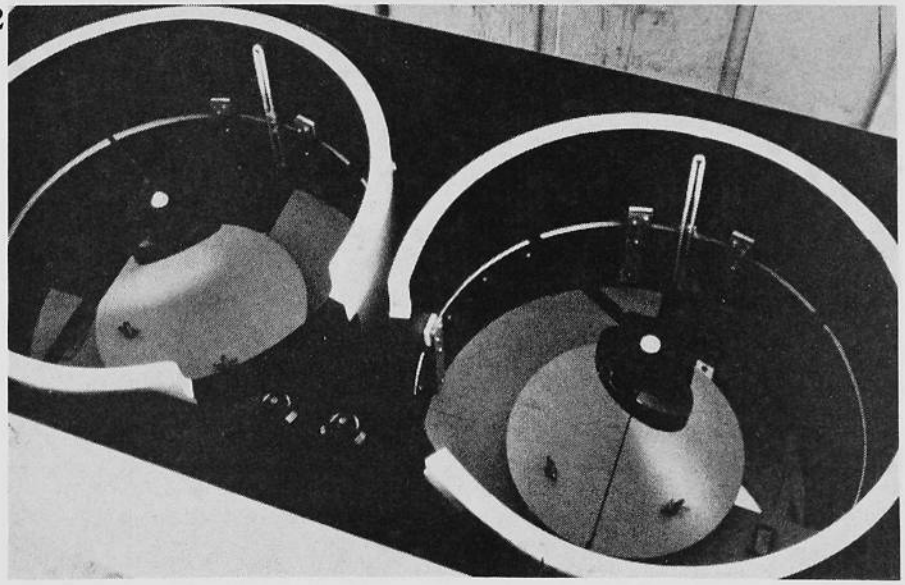

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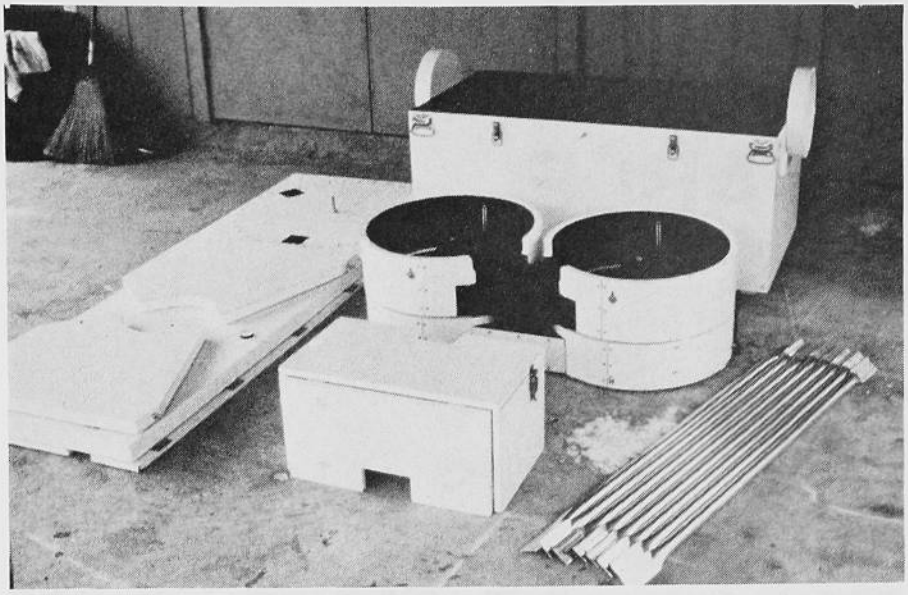
people have used it and only one or two asked to change the eye spacing. Of course, many could have had a better view with only a minor adjustment, but the allowable error is considerable, as you can see for yourself by testing it with a small binocular. But I have provided for interocular adjustment on the 17″ by having the forward sections of the secondary module counterrotate on Teflon pads.

I use rubber casters instead of Teflon pads as azimuth bearings. With such a heavy telescope, the pressure required to move a Teflon system in azimuth would be considerable, and the truss design would flex a small amount and unmerge the images.

The secondary and tertiary mirrors are overcoated silver by Denton Vacuum in New Jersey. This coating is



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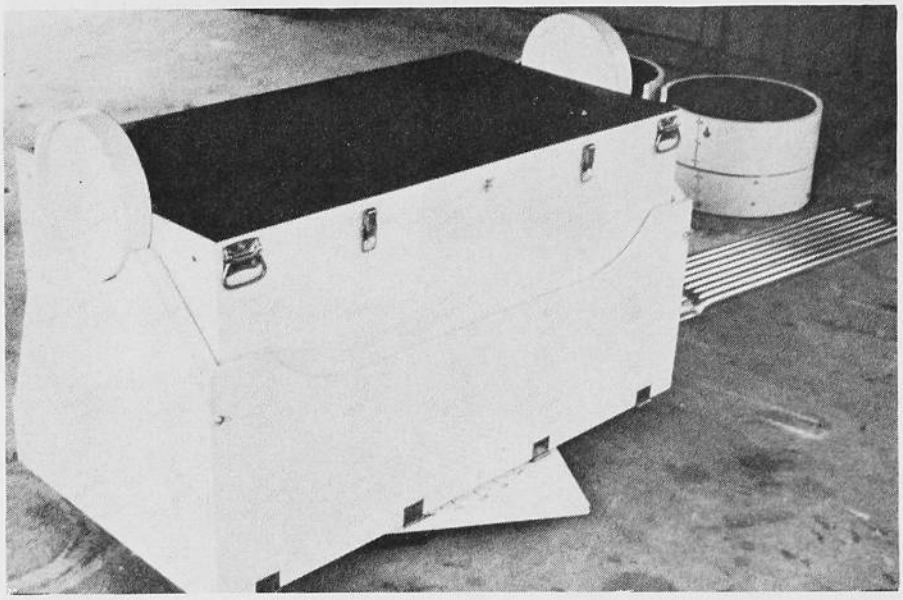

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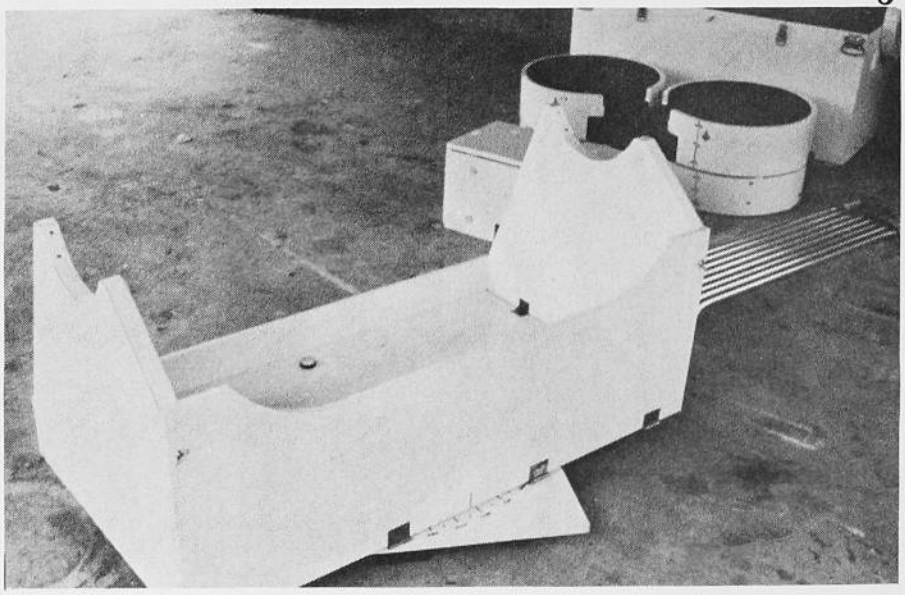

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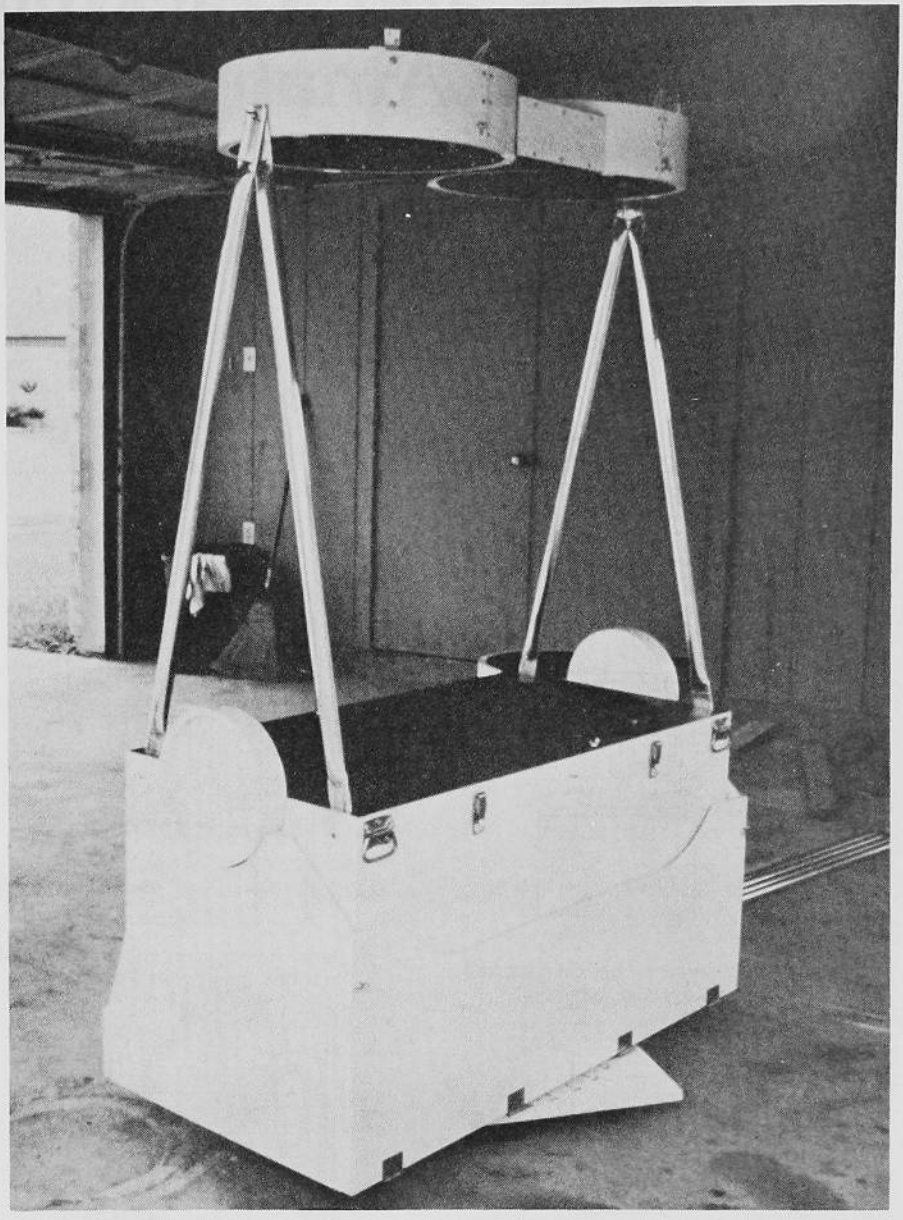
3. The upper end is now out of the box, and the side bearings have been attached.
4. Here's the rocker opened and assembled. Note the wing nuts which secure the front board.
5. The tube box in the rocker.

about 99% reflective as opposed to 88% for standard aluminum. So the overall throughput of the system is about 86%, an 18% gain over the 68% of a three-mirror system coated with standard aluminum. This 18% advantage cost $150, or about $8.30 per percentage point. Coating the primary mirrors would cost $700 more, giving an additional 11% for an overall efficiency of 97%. But the cost for the additional efficiency would be about $64.60 per percent.

To collimate the system, I look through the two focusing tubes, the eyepieces removed, then adjust the mirrors until all are merged as though you were looking through a single Newtonian system. The instrument holds collimation pretty well when taken apart and then put back together, usually requiring only a final fine merging of star images for each observing session. Once thermal equilibrium is reached, there is usually no need to remerge at low magnifications, though with the use of higher magnification eyepieces, little touch-ups help from time to time.

Since the telescope stands pretty tall when pointed near the zenith, I made an observing stool. It unfolds to become a diaphragm board that protects the

6. *The bottom section of the upper end now held by the first two pairs of struts.*
7. *After attaching the diagonal assemblies, Lee looks through the telescope to check its collimation.*



6

primary mirrors and serves as a Velcro platform on which accessories are stored for transport.

There are many possibilities for large binocular designs. Generally, since I feel it offers the greatest advantages to deep sky observers, a Newtonian system on a Dobsonian mount is the most obvious. But I'd really be interested in seeing designs for other applications. The following are a few fundamentals to remember in designing your own:

- The optical elements must be very positively mounted to avoid loss of collimation when moving the telescope around.
- Provide for fine adjustment of the lenses and/or mirrors, particularly as it affects the vertical merging of the two images.
- There are many design possibilities for bringing the light paths together and for providing interocular adjustment, but this can be tricky as regards field orientation, so I suggest you test the method before committing to the design.

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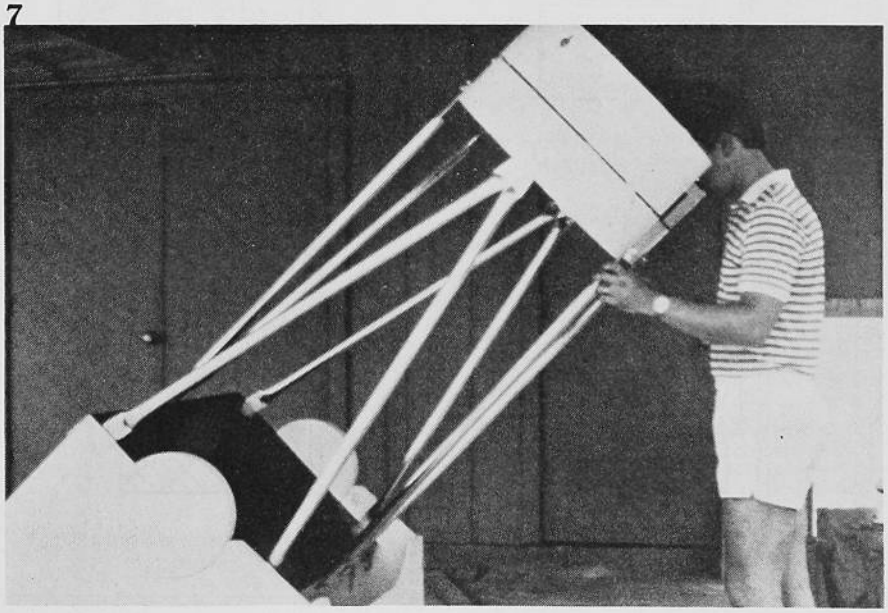
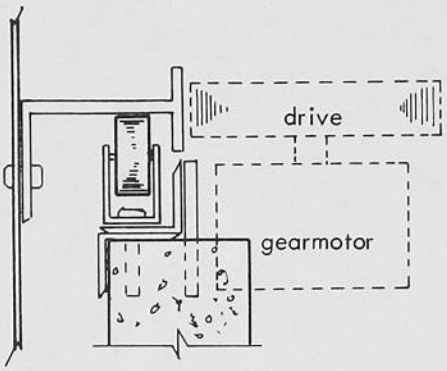
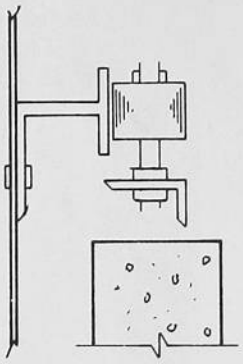


7

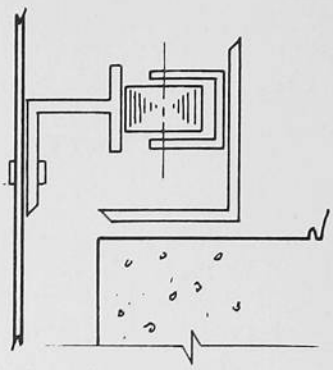
Tracks and Tracking Systems for Amateur Domes



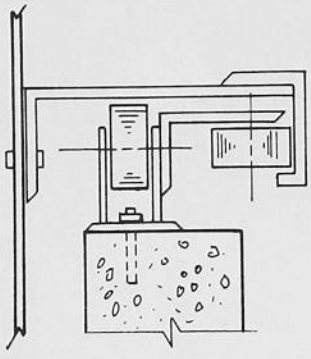
rubber roller with horizontal gearmotor drive, single pin.



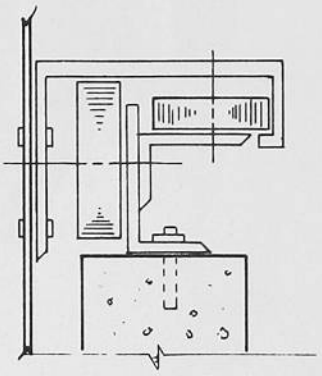
vertically mounted metal guide bearing.



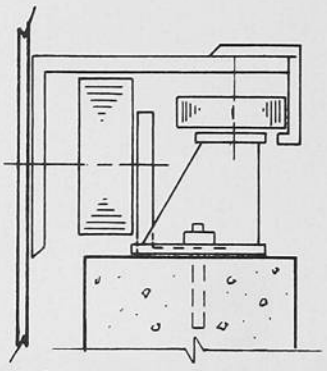
horizontally mounted guide roller.



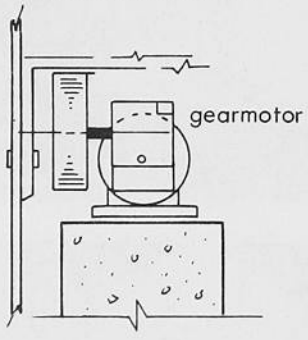
combination rubber carrying and guide roller assembly.



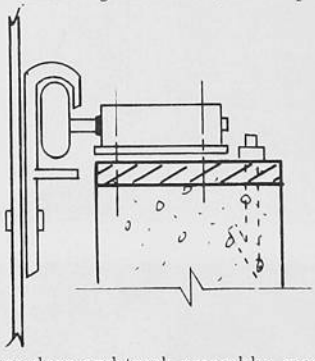
large rubber carry roller, horizontal rubber guide roller, double pin.



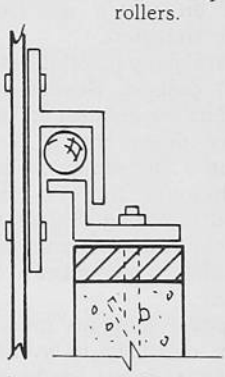
combination rubber carry and guide rollers.



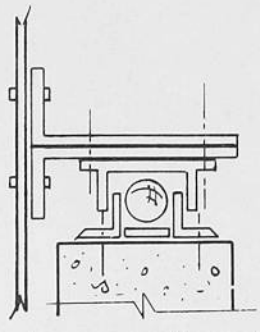
carrying drive rubber roller with electric gearmotor.



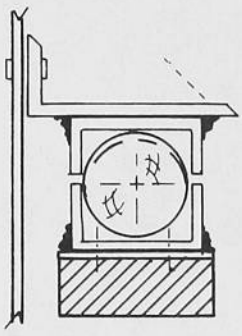
garage door and track assembly; may suffer crimping problems.



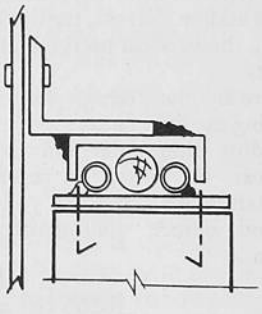
ball bearing, upper and lower pinning; balls may "bunch up."



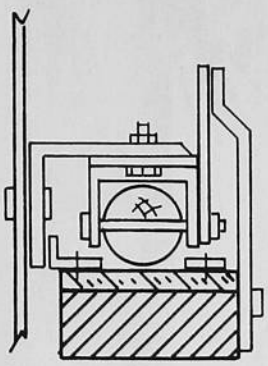
ball system, upper and lower pinning; a "free" system.



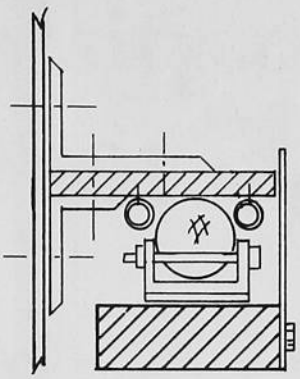
large ball system, welded upper pinning.



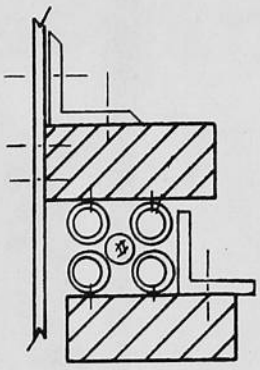
ball bearing and conduit, upper pinning; conduit ⅔ bearing diameter.



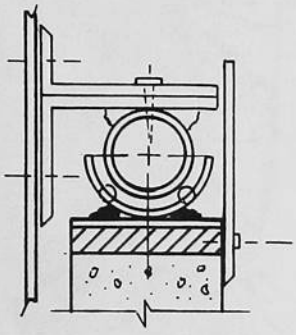
vertical encased ball bearing on wood track with metal guides, lower pinning with dual vertical guide bars; 2x4 footing for wooden track.



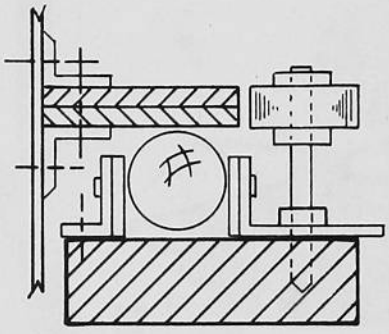
encased ball bearing at lower position, conduit guides with vertical guide bar, double pin.



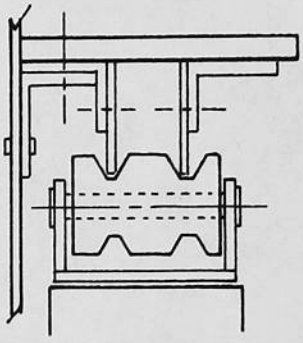
conduit and ball bearing system with vertical guide bar; balls tend to "bunch."



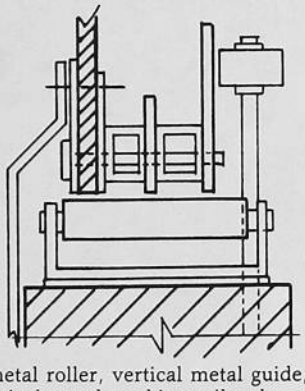
welded conduit, upper and lower pinning: lower conduit sliced in half and drilled every 12"; small bar bearings carry upper conduit.



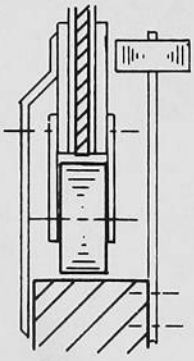
large ball bearing system, vertical mounted guide bearing (metal), double pinning.



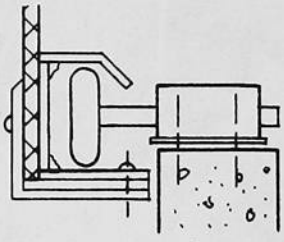
rubber boat roller with twin vertical rails, single pin in lower position; some crimping in motion.



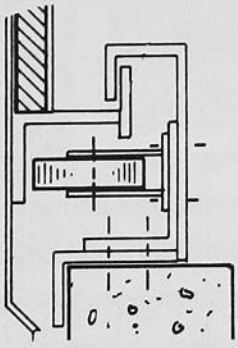
metal roller, vertical metal guide, vertical metal tracking rails, channel spacers; external flashing.



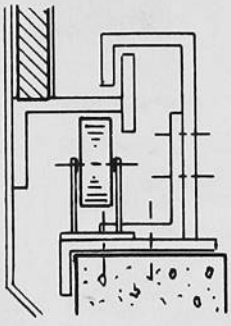
rubber carrying roller with vertically mounted guide roller; flimsy guide system.



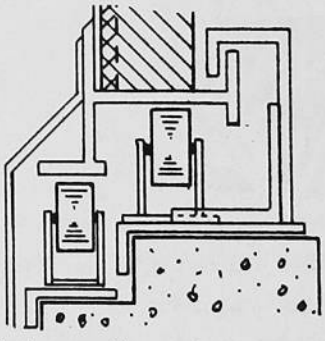
attempt to support dome wall as a unit, heavy duty garage door roller; tends to bind in cold weather.



guide roller assembly (A) with "hold down" and vertical guide bar.

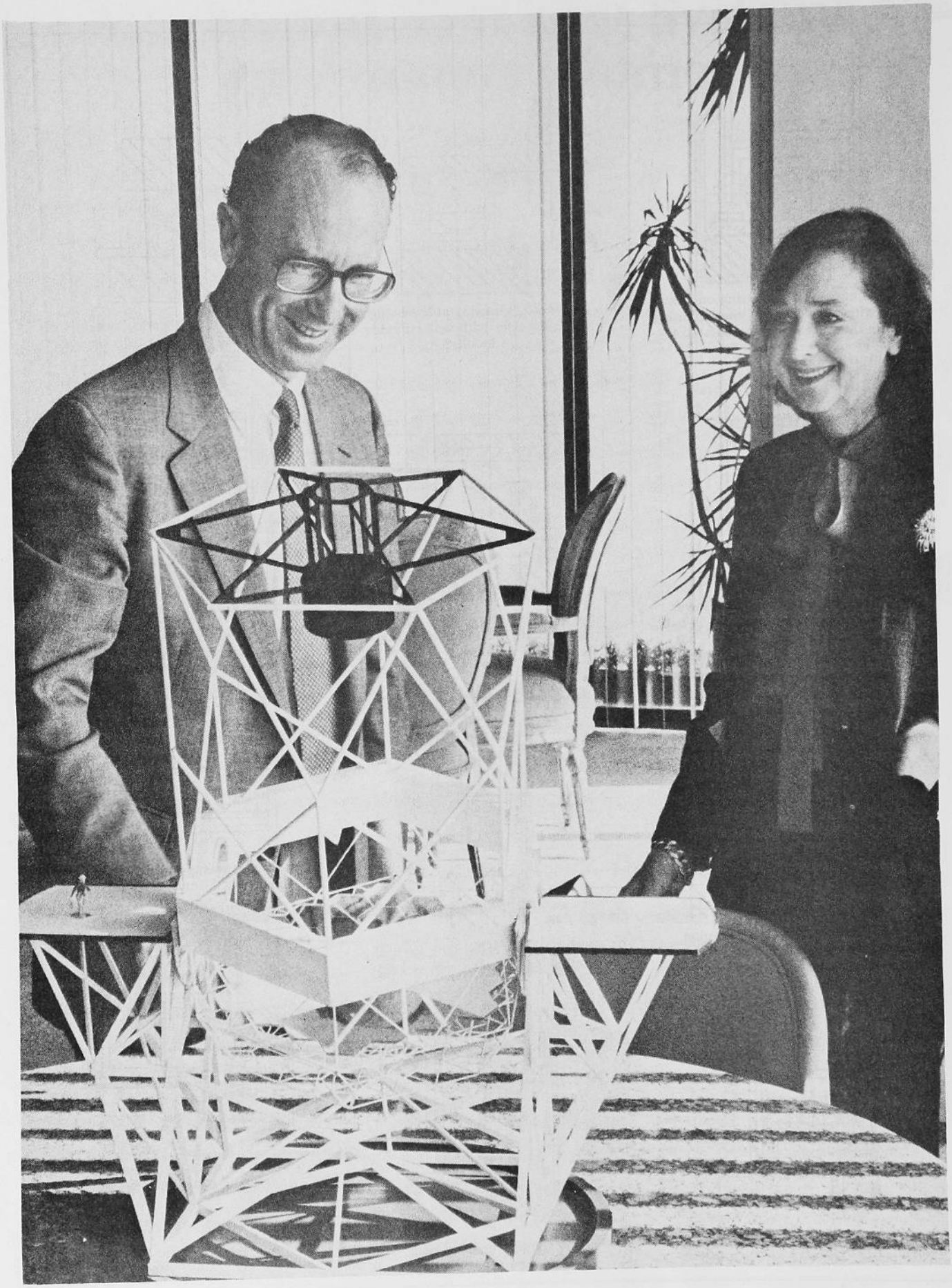


carrying roller matched with "hold down" and vertical guide bar.



dual carry rollers with guide roller (A); tracking plate could be wider.

Jerry R. Warner
1010 East Fairchild
Iowa City, IA 52240



Telescope Making #24

The University of California Ten Meter Telescope

I. The Hoffman Bequest

The largest single private gift in the University of California's 116-year history has been received from the Marion O. Hoffman Trust for creation of the world's largest and most powerful telescope — a UC project being planned for construction on Mauna Kea, a 14,000-foot peak on the Big Island of Hawaii. The Hoffman donation, valued at $36 million, is in the form of property in California and New Jersey, art masterpieces, and cash equivalents.

"Mrs. Hoffman's trust called for this large gift for construction of the Ten Meter Telescope and a 'rapid distribution' of the assets," says Ursula C. Niarakis of Long Island, New York, the sole trustee of the Marion O. Hoffman Trust. In her trust, Mrs. Hoffman, who died in Los Angeles December 16, 1983, stated that the funds from her estate should be applied "to assist in the construction of the Ten Meter Telescope project as planned by the Board of Regents of the University of California."

Acting in her capacity as sole trustee for the Hoffman Trust, Mrs. Niarakis, who was a longtime advisor and administrative assistant to Mrs. Hoffman and her late husband, Maximilian, has followed through on both the spirit and the letter of Mrs. Hoffman's last wishes, says UC President David P. Gardner. In accepting the gift on behalf of the UC Board of Regents, Gardner said, "We are happy to honor the Hoffmans by naming the project the Maximilian E. and Marion O. Hoffman Observatory.

"We are most appreciative of Mrs. Niarakis's dedication to fulfilling Mrs. Hoffman's request," says Gardner. "We are grateful for the enthusiasm shown by family members in commenting on this magnificent memorial to Maximilian and Marion Hoffman." Marion Hoffman's brother, Edward Kain of San Jose, California, and sister, Doris Chaho of Irvine, California, have also reported Mrs. Hoffman's desire to see the Ten Meter Telescope become a reality through her funding of it.

Mrs. Hoffman's late husband, who died in 1981, was considered "the father of the import car in the United States." It was because of his love of precision mechanical devices that Mrs. Hoffman selected the Ten Meter Telescope as a fitting and lasting memorial to him. Hoffman's lifelong love of sleek racing cars and his extensive personal connections with prominent automobile manufacturing families of Europe led to his importing of foreign cars, such as Jaguar, Volkswagen, Porsche, Mercedes-Benz, Alfa Romeo, Lancia, and Fiat.

His original Hoffman Motor Corporation showroom on New York's Park Avenue was designed by Frank Lloyd Wright; leading celebrities of the day were among Hoffman's clients. In several cases, Hoffman helped create the designs and engineering advances featured in imported European cars, such as the Porsche Spyder, the BMW 507, and the Mercedes 190 and 300SL.

II. The Project

The 200-inch (5-meter) Hale Telescope on Mount Palomar was designed in the 1930s and completed after WWII. Today, some forty years later, it is still the premier instrument of ground-based optical astronomy. However, while this telescope has had a surprising longevity, it could not meet all of the needs of astronomical research. Indeed, in the last twenty years, a host of small instruments, all in the 100 to 160-inch range, have been constructed in response to the demand for astronomical observations.

At the same time, the need for telescopes much larger than the Palomar instrument has long been recognized by the astronomical community. However, their construction required the development of entirely new technological approaches. In recent years, new techniques have finally been developed so that a larger telescope can be built.

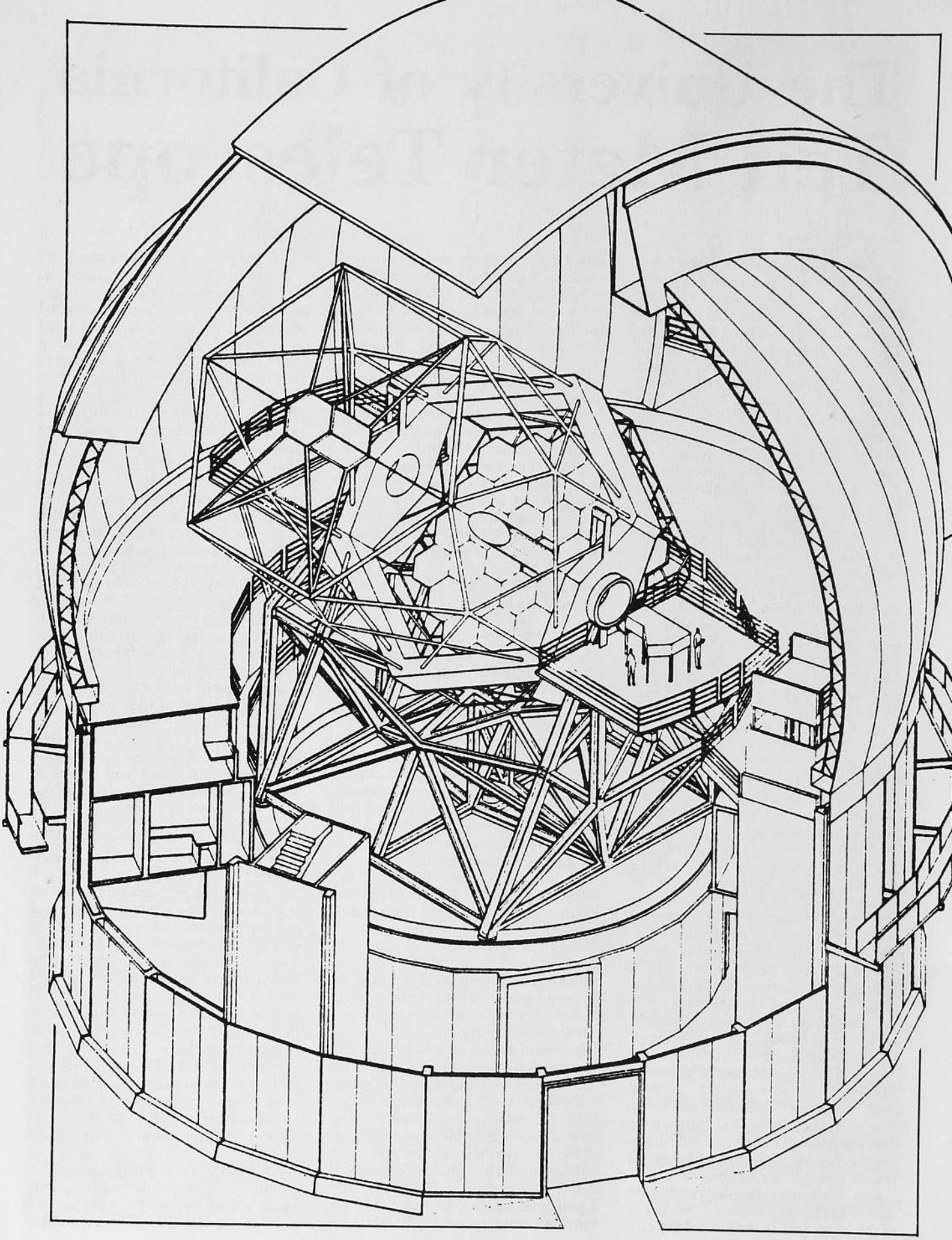
Studies of advanced concepts for the construction of telescopes of very large aperture were initiated at the University of California in 1977. Between 1977 and 1980, UC astronomers investigated a broad range of possible approaches. In 1980 a special committee of distinguished scientists recommended to the President of the University that a particular concept be adopted. This concept envisages the replacement of the single primary telescope mirror by a large number of mirror segments. These segments, all parts of a single optical surface, are kept in mutual alignment by a system of sensors and actuators which are ultimately controlled by a computer. Compared to the Hale Telescope, the UC Ten Meter will have four times the light-gathering power and will permit the study of a volume of astronomical space nine times greater.

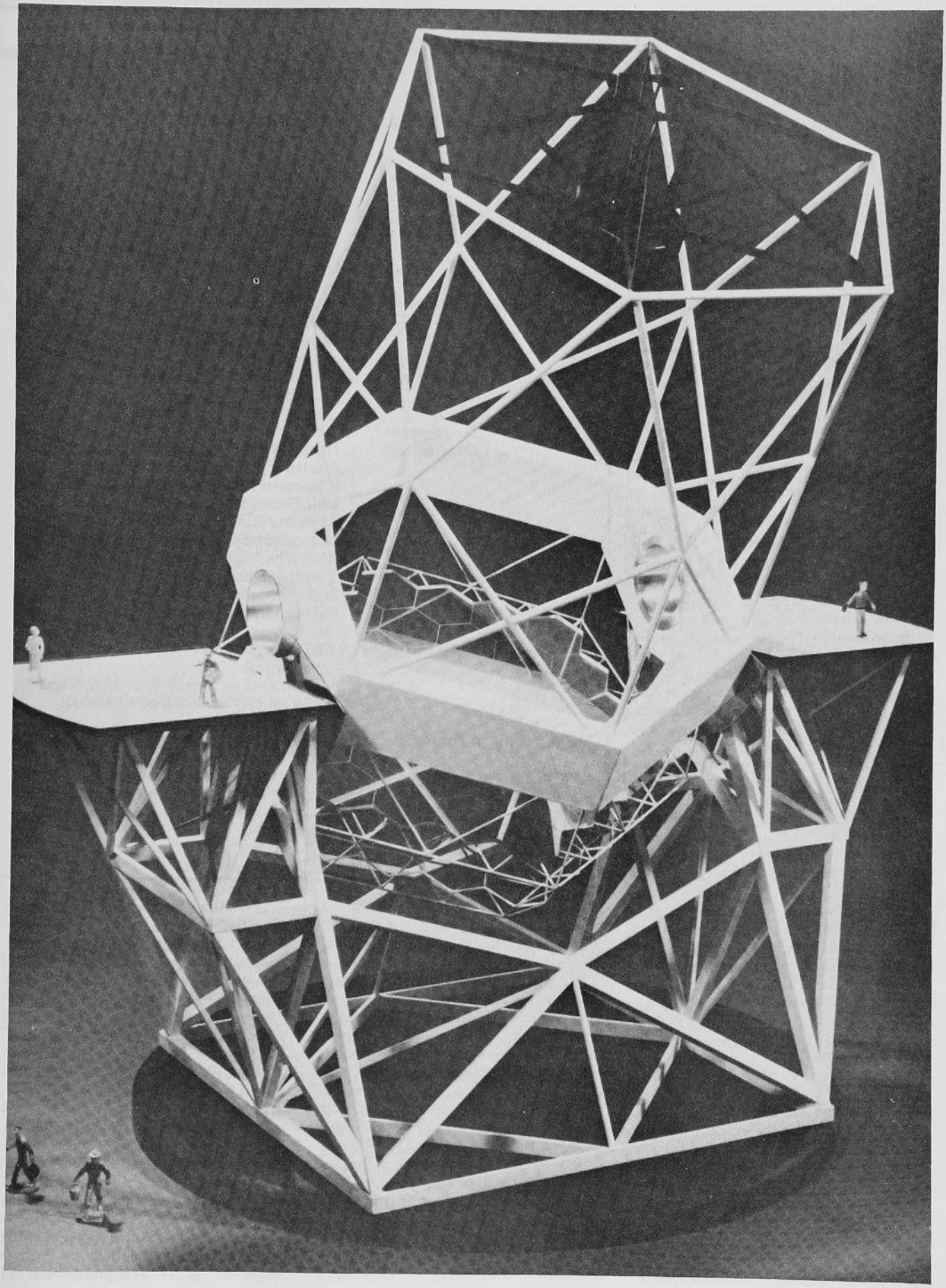
The UC Ten Meter Telescope will be the largest and most powerful optical/infrared instrument in the world. When operational, it will be able to produce images of unprecedented clarity and detail. It will be able to detect faint distant objects so far away that their light has been on its way since near the beginning of time. In addition to being able to look farther back toward the beginning of the Universe as we now know it, the telescope will allow closer objects to be studied in much greater detail than is possible with existing instruments. The telescope will be able to observe new stars in development or see new solar systems being born. In short, this telescope will permit research which will lead to a better understanding of the origin and structure of our Universe.

III. The Ten Meter Telescope (TMT)

The telescope consists of the structure and drive systems required to support and position the 36 hexagonal mirror segments which, jointly, make up a primary mirror with an effective diameter of approximately ten meters. The mirror has another short focal length of 17.5 meters. The mirror segments must be kept aligned to a precise optical figure in spite of changes in the gravitational force and changes in temperature and wind buffeting. This is accomplished by a system of sensors and actuators under computer control which measures the relative positions of the segments and, if necessary, re-adjusts their position 100 times per second.

Astronomical pointing is achieved by means of an altitude-azimuth mount, again under computer control. The essential characteristics of the telescope





structure and of the primary mirror are specified below:

Preliminary Telescope Structure Characteristics

Length	22 m
Elevation axis to mirror vertex	4 m
Elevation axis to ground level	20 m
Weight	71.3 tons
Yoke and Nasmyth Platform	12 m
Total Telescope Moving Mass	158 tons
Lowest Resonant Frequency	5 Hz
Bearings	Hydrostatic
Drives	Friction
Slew Rate	4°/sec
Pointing Error	Less than 1.0 arc-second
Zenith Blind Spot	Less than 0.2°

Preliminary Primary Mirror Characteristics

Effective Collecting Area	76 square meters
Number of Segments	36
Primary Focal Length	17.5 m
Segment Thickness	.075 m
Material	Zerodur
Segment Weight	400 kg
Radius of Curvature	35 m
Mirror Segment Size	1.8 m hexagon

IV. Telescope Enclosure

The telescope enclosure, a building-dome combination, is currently under design by MBT Associates of San Francisco. A number of design concepts to meet the needs of the telescope and the astronomers are being investigated. In general, such a facility might have approximately 10,000 square feet for computer rooms, electronics shops, mechanical shops, mechical equipment, aluminizing facilities, control room, coude room, and storage and staff facilities, A visitor gallery will permit inspection of the telescope by the public without interference with research programs.

Thermal control of the observing area is known to be a critical necessity to achieve good optical performance. This requires that all access to the observing area be carefully controlled and buffered to prevent heat from entering. Oxygen enrichment of the air in certain parts of the building is under consideration.

V. Site

The Ten Meter Telescope will be located on the island of Hawaii near the peak of the dormant volcano Mauna Kea. The site is considered to be one of the finest sites for optical and infrared astronomy in the world. The site was chosen based on the following considerations: (1) the site provides sub-arc-second seeing a significant part of the time; (2) the altitude results in low water vapor content in the atmosphere; (3) the site has a large fraction of photometric quality observing time; (4) the site is developed and has an existing infra-structure for support facilities.

The site is located within the Mauna Kea Reserve. Several large astronomical installations are already sited in the Reserve: the University of Hawaii 88-inch telescope, the United Kingdom Infrared Telescope (UKIRT), the Canada-France-Hawaii Telescope (CFHT), and the NASA Infrared Telescope Facility (IRTF). Two new facilities for Cal Tech and the United Kingdom-Netherlands are presently under construction. The site of the Ten Meter Telescope, a 1.5 acre area, is at the summit of a cinder cone located approximately 850 feet directly west of IRTF. The cinder cone peak is at an altitude of 13,618 feet.

The characteristics of the site are specified below:

Site Characteristics

Elevation	4116 m
Latitude	19° 49′ N
Longitude	155° 28′
Mean Temperature	5° C
Median Diurnal Temp.	12° C
Median Wind Speed	16 km/h
Median Humidity	43%
Cloud Cover	
Photometric	45%
Spectroscopic	25%
Covered	30%
Sky Brightness	23.0 mag/arc-sec^2
Precipitable Water	Less than 2 mm

The 8.5 mile road section from the Hale Pohaku to the Reserve Area is unpaved. It is acceptable but of

Fact Sheet on the University

Permanent Name:	Maximilian E. and Marion O. Hoffman Observatory.
Owner:	The Regents of the University of California.
Participating Units:	The Lick Observatory; UC Berkeley; UCLA; UC San Diego; UC Santa Cruz; The Lawrence Berkeley Laboratory.
Project Scientist:	Jerry E. Nelson, Astrophysicist, Lawrence Berkeley Laboratory, and Professor of Astronomy, UC Berkeley.
Project Manager:	Gerald M. Smith, by contract with Caltech.
Management Committee:	Harold K. Ticho, Vice Chancellor, Academic Affairs, US San Diego, (Chairman); Robert P. Kraft, Director, The Lick Observatory (US Santa Cruz); Raymond L. Orbach, Provost, College of Letters and Sciences, UCLA; Roderic B. Park, The Vice Chancellor, UC Berkeley; David A. Shirley, Director, The Lawrence Berkeley Laboratory; Robert L. Sinsheimer, Chancellor, UC Santa Cruz.
Executive Architect:	MBT Associates, San Francisco.
Site:	Summit area of Mauna Kea, 13,636 feet (4,156 m) elevation, Island of Hawaii.
Project Timetable:	Design and testing completion by mid-1984; mirror production 1884-87; Observatory construction 1985-88; assembly and installation 1986-89.

California Ten Meter Telescope

Completion Date:	1988-89.
Cost:	Estimated (1983 plus inflation) $95 million.
Primary Mirror:	10 meter (approximately 400 inch) diameter hexagonal paraboloid: fully segmented; composed of 36 hexagonal segments individually supported in a lightweight frame cell; segments are 1.8 m wide by 7.5 cm thick.
Mirror Control:	System of sensors measures relative positions and orientations of mirror segments; actuators move and correct segment orientations; and a computer algorithm translates sensor information into desired actuator motions.
Total Mirror Weight:	14.4 tons.
Moving Weight of Telescope:	141.6 tons.
Telescope Mount:	Altitude-Azimuth.
Focal Length:	1,750 cm.
Major Focal Configurations:	Prime Focus Camera (F/1.75); Wide Field Camera (F/2.0); Infrared Focus (F/35); Nasmyth/Cassegrain Foci (F/15).
Angular Field:	About 20 minutes.
Observational Capability:	From 0.3 to 30 microns.

minimum quality. Electrical power for the existing telescope installations is provided by a local generator. Planning assumes that commercial power will become available in the near future and that the more hazardous portions of the road will be paved. The use permits for such improvements were approved by the State of Hawaii in February of 1984. The Ten Meter Telescope Project will share in the capital costs of these improvements.

Support facilities to accommodate the observers and the maintenance staffs of the existing telescopes are available at Hale Pohaku at an altitude of 9,000 feet. Augmentation of these facilities will be required for Ten Meter Telescope personnel; present plans call for a dormitory building with fourteen sleeping quarters.

The Ten Meter Telescope will also require a sea-level support facility. This facility will include staff offices, equipment maintenance areas, instrumentation repair shops, computer installations for data analysis, and communication links with the Mauna Kea summit and the mainland.

VII. Present Status

A committee of UC astronomers met in 1978 to select the method of approach for making a segmented-mirror telescope. UC Berkeley Astronomer Jerry Nelson led the discussion for a segmented mirror and was given the honor — and the responsibility — of overseeing creation of the innovative technology involved. He now serves as project scientist.

The TMT project involves four UC campuses with major astronomy interests — Berkeley, Los Angeles, San Diego, and Santa Cruz. A six-member executive management committee, headed by Dr. Harold Ticho of UC San Diego, has overall responsibility for the project, and a committee of UC astronomers and engineers considers scientific and technical issues and gives direction.

In addition, agreements are being worked out with the University of Hawaii for use of the observatory site atop Mauna Kea and for scientific collaboration. The site was picked because it is free from cloud cover, it provides excellent possibilities for making observations, and it offers new possibilities for viewing the southern sky. Other but smaller observatories are already located there.

A working demonstration of the innovative mirror control system is scheduled for completion this June at Lawrence Berkeley Laboratory. The success of that demonstration will give the scientists assurance that a full-scale telescope of 36 segments can be controlled with the required precision. Another aspect of the project still in the development stage is the manufacture of hexagonal segments. Each segment must have a different curvature in order to contribute to the overall surface of the final 36-mirror array.

Nelson, who had to devise a fast production method to fabricate the mirrors, invented "stressed mirror polishing," which involves clamping a glass disk in a vise and stressing it into a warped shape. After that, standard glass polishing techniques can be used. But when the finished glass is released from the vise, it takes on the exact asymmetrical curvature needed to play its part in the 36-segmented-mirror surface. (After each segment is polished to the proper curvature, its edges must be cut so its original round shape becomes hexagonal.) This novel approach to mirror polishing is being tested by scientists at the Kitt Peak National Observatory.

With the large donation from the Hoffman Trust, the work at UC can continue without impediment, but there still remains a need for additional funding. "The Hoffman gift will be part of a nearly $100,000,000 package to be put together by the University of California and which could include other donors, other institutions, and interested agencies of government," says Judith Woodard, UC assistant vice-president for university relations. "The particulars for such a package have not as yet been arranged," says Woodard. The present schedule calls for the Ten Meter Telescope to be completed by the end of this decade. ■

Letters

Dobsonians à la francaise

Dear Sirs / I seize the opportunity to say to you that the Dobsonian is making its entry in France. Magazines for amateur astronomers are beginning to talk about its philosophy and its techniques. The success and popularity of my own 17.5″, the first one here and widely publicized, surely help quite a bit.

With a friend, I have tried to use the Foucault test on the 17.5″ mirror in its floatation cell, but it is almost impossible to do good measurements. We would like to use the Hartmann test, but we can't find examples of its use in amateur magazines, explaining how the screen's holes are designed and the photographs made and also if it is possible to avoid a filar micrometer. It seems that 17.5″ or other big thin mirrors (commercial or homemade) are not tested by their owners in terms of waves — why?

I hope that someday TM will publish an article about the Hartmann test as applied to big amateur mirrors with short focal ratios.

Christian Hanon
17 Bd de la Republique
92370 Chaville
FRANCE

— In the Hartmann test, a grid of openings about 2% the diameter of the mirror is placed over the mirror. Two photographic exposures of a star, one inside focus and the other outside focus, are made. The positions of the individual holes are measured, then the "rays" traced back to their intersection point at best focus. The test is not feasible without a clock-driven mounting and an accurate method of measuring the spot positions, so it is not suitable for use with a Dobsonian.

Why not use the Ronchi test on a star to check the mirror's edge? I would also recommend you read Bob Kestner's articles in TM#12, TM#13, and TM#16 for more ideas on testing stellar images directly. Although these methods do not produce a wave rating directly, they will give you some idea of the optical quality of the mirror, which is, after all, what matters.

British TN, CPRB, FRAS

Sir / Although English born and bred, from 1949 onwards, my hobby bibles were *Amateur Telescope Making* book 1, 2, and 3. Guided by these excellent volumes, I couldn't help but become an avid Telescope Nut and member of the Carborundum, Pitch, and Rouge Brigade. I've built telescopes and hand-worked dozens of mirrors up to 14″ diameter. Far more books now exist on this subject, but for my money the old *ATM* series is still the best and most comprehensive available.

Although now a skilled optical worker, able to produce mirrors large or small, my well-worn very tatty rouge-stained *ATMs* are still regularly used for reference, I have also followed many new American examples, recently building a 14-inch Dobsonian which I'm delighted with. A short while ago, I asked my news agent if he could recommend a monthly astronomy magazine. Guess what! He recommended another American publi-

cation, *Astronomy*. Very impressed, I placed a regular order.

After 34 years of mirror making/telescope building, I have much to thank American astronomers-mirror makers for. Good luck in the future to your excellent magazine. I sincerely hope its sales increase in England. I shall certainly sing its praises.

I would welcome American pen pals.

Brian Slade F.R.A.S.
"Santa-Maria"
8 Queens Rd.
Minister
Sheppey Kent
ME12-2HD
ENGLAND

USA Has Bargain Prices?

Dear Robert E. Cox / In reading *Telescope Making* #20 from 1983, I saw your article about the Riverside 1983 meeting, where you wrote many things which are amazing to me. I'm an amateur astronomer in Holland and I use a 75mm aperture 1200mm focus refractor, and I'm satisfied to work with it — I have very good Moon observations. But in your article on page 16, you say that a man bought a 5″ refractor lens at a meeting for $20, and you also mention war surplus items.

My question is this: If you are willing, could you tell me some addresses where I can buy war surplus lenses, because I'm a retired man (66) and the prices of optics in Europe are very high. The higher your dollars, the higher our prices! I'm looking for an objective from 4 to 5 inches in diameter and a focal length of 60 or more inches — and of good quality.

I hope you'll be so kind to send me, if possible, an address where I can get the good information.

Jack Renes
Do. Pasmastraat 21
3981 C.W. Bunnik
The Netherlands

— It is unfortunate that sometimes a note in an article, such as you saw, does not fully explain the situation involved. The lens mentioned was a "war surplus" item whose quality is satisfactory only for use in a low-power finder application. This lens cost the original owner more than he sold it for, but on finding he had no use for it, he sold it to someone who would make use of it.

There are "bargains" to be found at such meetings, but usually at a more normal figure. I knew an amateur who picked up a fine professionally-made 75mm f/15 refractor for about $150. I was most pleased at the definition when viewing with it. However, one never knows what will be available at such a meeting until they attend. At this time I know of no way a foreign amateur could locate and buy equipment easily. So many years after the war, there is little good "war surplus" left, and that is another difficulty.

Possibly you could contact an amateur in the states telling him what you are looking for and the price you could pay, and they could see if it was available at the meeting. Of course, there is still the problem of having it shipped to you and the customs.

The best possibility is to ask American amateurs who make their own instruments and have a surplus of optics to offer them at a low cost to people like you. I am sure there are many home-made instruments that are no longer being used and stored in the attic or cellar that people might be induced to let go of for just a little money.

Another possible solution, which would take time, is to try to set up some method of getting instruments from amateurs through the United Nations. One of their educational units might be able to set up such an arrangement. However, I worry about the politics of such an idea — but one can't succeed without trying.

We intend to publish your letter in TM, possibly with some of the suggestions I am mentioning, so perhaps you will be lucky and get a set of telescope optics from one of TM's readers.

Robert E. Cox
Associate Editor

Making an MMT?

Dear Mr. Berry / My interest in observing galaxies and clusters of galaxies led me a year ago to order a 17.5″ optics set from Coulter Optical Co., which I just recently received. I am still finishing up the Dobsonian mount, so it hasn't seen "first light" yet. In any case, I am thinking already about the future. The 17.5″ was the first telescope I have ever built (everything except the optics, of course), and my success has helped to inspire me to think quite boldly about different designs. Since light grasp is important to me — more than any other factor except size and weight — I am hunting for a design which will give me more of the former while keeping the latter within reason. Perhaps this is impossible and the only such telescope is in my dreams! But I am optimistic.

Coulter's 29″ optics are fantastic as far as light grasp is concerned, but the cost and especially the tremendous size and weight of the telescope built around them, led me to reject a 29″ in favor of a 17.5″; I decided if I wished to go to that size range, I had to find another way.

This has led me to the topic which I wish to find out more about. Why haven't more

ATMs attempted to build multiple mirror telescopes (MMTs)? I know of only one effort by two Boston ATMs, Kenneth Launie and Harold Robinson, who displayed their MMT at Stellafane in 1979 (see TM#5). I am curious and puzzled as to why there haven't been more attempts.

Is there some inherent difficulty in making MMTs? I realize that alignment and collimation of optical elements might pose a problem, but surely not an insurmountable one? Or perhaps it is the combining of images that is the problem? This leads me to ask you a question — what is a beam combiner? Are these readily available and how could they be used in an MMT-type scope? As you can tell, my ideas are rather vague and hazy but any information you can give me would help clarify things. Personally, I feel an MMT with relatively few mirrors, maybe four, would allow greater light grasp while keeping the scope relatively compact.

Jeffrey Pignatora
83 Homestead Drive
North Tonowanda, NY 14120

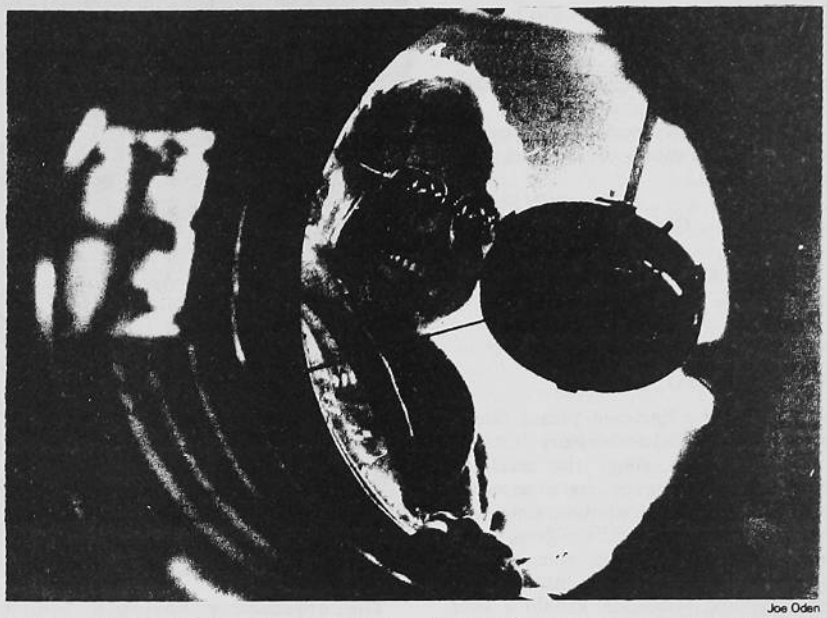
— The Launie-Robinson MMT is still incomplete, to the best of my knowlege. The major problems in building such an instrument are: 1) matching the focal lengths of the individual optical systems; 2) aligning the individual optical systems; and 3) maintaining precise collimation of the individual systems relative to one another once the instrument is assembled. These are formidable obstacles. The simplest beam combiner is merely a pyramidal prism — the individual beams bounce off its surface and come to a common focal point. I would not expect one to be hard to come by — maybe a few hundred dollars from Rolyn or other industrial supplier. Whether the problems are insurmountable remains to be determined.

TM Alive in St. Paul

Dear Richard / The enclosed newspaper article tends to indicate that amateur telescope making is still alive and well in St. Paul. The reporter did a fair job at that.

My interim telescope class is limited to six and filled up fast. They started grinding their 6″ f/6 mirrors from scratch on Tuesday, Jan. 3, and today, the 5th, all six have finished their #2100 grit and are ready to start polishing tomorrow. I will be dividing the class into two groups of three each. One group will start out with the classic method of mirror on top for only five minutes and then we'll photograph the Ronchi band patterns. The second groups will go "the Macalester Method" and use lap or tool on top for the same period and then have their patterns photographed. Wanna make any bets?

My son has bought a classic farm about ten miles south of Mankato and the skies are remarkably black. The bright lights, for once, are to the north. He should be moving in early this Spring, and the first thing he wants to do is build an observatory for Big Telescopes! The astronomy department at Mankato State is quite active, but has poor observing facilities. Maybe we can work out a cooperative deal with "the Macalester Annex"! I would like to move and remount the 25″ and maybe the large Perkin-Elmer



Joe Oden

Sherman Schultz's face is reflected in the mirror of one of many telescopes he has built at Macalester College, where he is a professor of astronomy.

Telescope builder awaits comet

By Steven A. Smith
Staff Writer

Somewhere in the heavens, Halley's Comet is streaking toward its 1985 rendezvous with Earth.

As the comet nears, Sherman Schultz will be waiting with one of the country's largest telescopes in what some might consider the unlikeliest of places — the small Olin Hall Observatory at Macalester College.

Schultz, an optometrist and part-time college instructor, is hand-building the 34-inch reflector telescope that he and his Macalester students will use to view the comet.

"When it's done, it will be the 50th largest reflector telescope in the country. That says something, doesn't it?" Schultz said, smiling.

Schultz, 62, has been building telescopes since the 1930s. In recent years, he's broken new ground, building bigger and better instruments from materials he's scrounged, begged or borrowed.

> "When it's done, it will be the 50th largest reflector telescope in the country. That says something, doesn't it?
>
> —**Sherman Schultz**
> Amateur telescope builder

A 25-inch reflector telescope, housed in Macalester's observatory, is his biggest to date. The size of a telescope is the diameter of its reflector mirror.

The 34-inch telescope will be his biggest yet, the largest telescope in Minnesota and the largest amateur-built telescope in the country, he said.

Schultz built his first telescope from a hobby kit in 1934.

"I had a four-page folder from the kit's supplier and I was happy to have it. I haven't stopped tinkering since," he said.

Schultz joined the Macalester College faculty 30 years ago

Please see **Scope / 2C**

■ Continued from Page 1C

this week.

Although he's supposed to be a part-time instructor, it's his optometry practice that actually has become a part-time job.

Most days, he can be found in his Olin Hall laboratory surrounded by bound volumes of old astronomy magazines and bits and pieces of a dozen or more handmade telescopes.

He estimates 3,000 students have passed through his introductory astronomy classes through the years.

Students in an annual, one-month telescope building class have built more than 300 of the instruments, probably an amateur record, he said.

The new telescope taking shape in his workshop will be special, Schultz said.

At the heart of the instrument will be the 34-inch reflector mirror, a component that would cost $15,000 to $18,000 and weigh 700 pounds or more if it were purchased "off the shelf," Schultz said.

However, Schultz is building his own mirror from donated materials.

"It's an unusual design. Ordinarily, you'd have one piece of concave pyrex. That's the rigid structure that supports the reflective surface," he said. "I've used foot-square pieces of standard pyrex, epoxied together with a support structure underneath to form the mirror structure. The whole thing weighs about 150 pounds and can be handled by two people."

In the finished telescope, light from the distant celestial object being viewed will be focused on the mirror's surface and reflected back to a viewing lens. If the mirror is flawed or if it's reflective qualities are impaired, the image quality will be poor, Schultz said.

Once glued together, the pyrex must be ground and polished, prepared for the aluminized surface that will constitute the mirror. Schultz said he long ago lost count of the hours he's spent working on the pyrex and there are untold hours to go before the surface is ready for its coating.

"We'll do that at a laboratory here in the Twin Cities," he said. "It has to be done in a vacuum. The aluminum material is in the form of a solid wrapped around tungsten filaments. They put a high voltage through the filaments and in that vacuum, the aluminum turns to liquid. As it begins to gasify, it adheres to the pyrex surface."

The result is an aluminum coating that is six-millionths of an inch thick with a reflectivity of 92 to 94 percent, he said.

When the mirror is finished, Schultz will begin work on the superstructure that will support the telescope.

"I'm working to have it ready in time for Halley's," he said. "There's not much lead time left and it has to be finished in the next year or so if I'm going to be ready."

The telescope will be too unwieldy to move often so it probably will be housed in the Olin Hall observatory, a roof-top structure Schultz helped design. A half-dozen other sophisticated instruments, all built by Schultz and his students, are housed in the small observatory.

A movable roof gives Schultz a full view of the heavens.

"The value of all of this equipment? Well, if we bought it commercially, tens of thousands of dollars," he said.

Schultz said he's keeping a careful record of his work on the new telescope. The basic text for amateur builders was written in the 1920s and although updated regularly, remains essentially the same, he said.

"What I'm trying to do is test the limits of the amateur builder, to see how serious we can get," he said. "If we can build this instrument, then there's probably no reason why we can't go even bigger."

Letters

lens system we now have in operation. Halley's Comet's gonna catch hell!

Have you heard any good word on my #20 article yet? I had a couple of nice letters and it was well liked.

Sherman Schultz
Observatory-Planetarium
Macalester College
Physics and Astronomy Department
Saint Paul, MN 55105

Elevated Observing

Dear Mr. Berry / Enclosed please find a picture of my elevated observatory. It stands 33 feet high, well above the reach of intruders as well as the four feet of snow we can get some winters. In addition, since I am a manager for Combined Life of New York, I reasoned that I would someday be transferred. This allows me to lift the entire observatory for relocation should I ever decide to move.

I began the structure with 75 chimney blocks laid five feet into the ground on a cement footing. From below ground, I punctured a block and ran electric wire on a separate circuit underground from the house, up the blocks, and into the observatory. These four pillars of chimney blocks were then filled with field stones and concrete to make them each single, solid, and stable pillars, capable of holding several tons. I capped them with steel plates with large bolts protruding from the center.

My father arrived from Tacoma, Washington, at this point, to help. He could only stay for two weeks, so we worked almost around the clock. Four 2x6 beams, laid three together, were fashioned end to end for the base. Two x 8s were laid for the floor and almost 2 inches of plywood, laced with black paper, were put down for flooring.

Soon we were standing on a solid 16x16-foot floor. Texture 1-11 went up around 45 pieces, each 2x4 feet, cut at 11° to form a perfect circle. Cross parts and insulation were then put in, and the sides capped with a solid 2x6 ring. It was on this base that we laid an aluminum track, bent and pounded out by hand. Two L-shaped pieces ribbed together enabled an eight-inch industrial wheel to roll about in a circle, smoothly on grease with the touch of a finger.

On the morning we tested the track, my dad flew back to Washington State. A decision had to be made: close it up for the winter or build a dome. I decided to build the dome starting with the slot 33″ across and 14″ long. I angled up 2x4 and plywood bracing on six sides. My shutter doors were built inside the garage on days it was too cold or dangerous to chance February winds of upstate New York. The shutters move back and forth in the 2x8 box on smaller 3-inch wheels. I open the inside doors by using a swing hinge system — long poles, since the inside height to the dome ceiling is 11 feet. I can move the dome easily by myself, but plan to devise a motor to push-button-move my dome. On the exterior, I used pecan shingles stained to match the house.

The observatory houses a 14-inch Cassegrain, yoke-mounted telescope inside, custom-built for my lifelong needs as a central New York astronomer. It weighs 365 pounds. The observatory is fully insulated, heated, and paneled. It has tables and chairs, red observing lights, and lots of pictures on the walls. Star charts and celestial coordinates appear everywhere inside. With two or three keyed-up visitors, we always have a memorable time.

While looking at the Hercules Cluster the other night, I only noticed a minor vibration as my guest moved about. But as a rule, it's as solid as a hillside. Now my life-long boyhood dream of having my own observatory is a thrilling reality. It only takes 2.8 minutes to become fully operational and rotating. On cold wintery nights, under clear skies, I can climb through the trap door in the floor with Chris, my wife, and journey deep into space.

Dana Sidoran
New York

Reply to Pin Test Query

Dear Richard: / In reply to the letter Mirror Testing Woes: I tried the Everest pin method in 1965 on my 10″ f/6.2 parabola and abandoned it in favor of the Texereau zone testing method. I have used the zone testing method with great success and have never tried the Everest method since. The zone testing method works well with focal ratios greater than f/5, and very well at ratios of f/8 or greater.

However, at the lower f/ratios, below f/5, there are slope errors that can be hidden between the zones or inside the zones being tested, since the zonal mask segments are too large to have an even "gray" shade within them. The result is a gradation from light to black within each zone being tested. Then this becomes a judgment of shadows, once again. To minimize this effect, the number of zones must be increased to minimize the zone area and hopefully make it easier. Unfortunately, this does not make testing easier, rather it becomes more difficult since the zones are now narrow and harder to see due to lack of area and light.

The better test is the Dall Null test, at which time the whole mirror can be viewed at once and no micrometer measurements are necessary. There are two catches to using the Dall Null test:

1) Low light level; and

2) Need for an excellent quality plano convex lens.

The first problem can be solved by using a darkened room — something that you can live with. The second is much more difficult. Where's the excellent lens? I have a Zygo interferometer at my disposal and merely bought two lenses from A. Jaegers, inspected them and fortunately found one of them excellent. The other one was not usable. Without some testing method for the lens radius and flat side, you are at the mercy of the manufacturer. A high quality lens manufacturer who will guarantee the radius and finish the surfaces to 1/10 wave or better is then needed. You must also measure the focal length very accurately, or know the index to calculate it.

The Dall Null test and the Texereau zonal measuring method are remarkably good for mirrors of moderate f/ratios, and compare very well. For short f/ratio mirrors, the Dall Null test is superior; indeed, the Null test is superior for all f/ratios providing the test is done carefully with an excellent lens.

Richard J. Wessling
The Pines Observatory
5429 Overlook Drive
Milford, OH 45150

Digging in old Pop Mechanix

Mr. Berry / I have TM#21 in my hands and am reading it through. There are a lot of good ideas and information in it. I am at this time in the process of grinding a 4″ mirror. I have all 21 issues so far and last fall renewed for 2 years. I just renewed again last week for 2 more years before the increase (so I am good til TM#36).

Now, I need your help or your readers: I am looking for an article that appeared in either a *Mechanics Illustrated* or *Popular*

Mechanics. The article would go back about 30 years between 1950 and 1955. It was on a 3" table top telescope. If anyone remembers it or has the article, please contact me.

Duane C. Gerling
1706 Mt. Pleasant St.
Burlington, IA 52601

Teflon Source

Dear Richard / I've just proven that variety is indeed the spice of life! While searching for some catamaran parts (sailing is my other passion) I came upon three Teflon disks packaged in plastic envelopes. These turn out to be mast bearings for Hobie Cats, on which the masts rotate as the sails are trimmed.

Needless to say, as a Dobsonian builder, I'd rather have these bearings for a different purpose (come to think of it I wouldn't mind a Hobie either!). At any rate, they come three to a package and measure 1½" x 3/32", a trifle on the thin side but if you're real careful about countersinking the heads of the brads they work well!

John Alfonso
638 Cornell Avenue
Albany, CA 94706

— Teflon is everywhere! Teflon toilet doohickies are, for example, available from plumbing stores, though these are not as good as the Hobie mast bearings probably are. Before paying a premium price for a manufactured part, always check that a plastics supplier (in the Yellow Pages under "Plastics — Rolls, Sheets, and Rods") doesn't have cut-off ends and scraps for half price.

More on Slitless Testing

Dear Richard / I really like the way my article/letter looked in TM#22. There were a few errors, so to straighten them out, let me list them:

1) the longitudinal aberration of a parabola at the center of curvature as measured by a moving source tester is r-squared/2R, but this is half that of fixed source testers, not twice.

2) my maximum slit width is not r-squared/4F, but (r-squared/2R)/4F. Someone must have dropped the extra characters sometime during the editorial processs, and the error propagated onward in the article, even getting removed from a later reference to this quantity. The very next quantity is correct, however, and the last line in the derivation is correct.

3) the inequalities I referred to were dropped and replaced with equalities. Everywhere that the reader sees "slit width equals," he should replace it with "slit width less than."

Otherwise, the article was fine. One thing that may not be realized by all of your readers is the "square bracket" rule — everything appearing in square brackets was added by the editor; everything else was written by me. That might fix up some extremely confused readers.

Slitless testers have been around since *ATM*, Book 1, where they were described rather incompletely, but they were first popularized in 1967 in articles by Ralph Dakin and Robert Cox in S&T's "Gleanings for ATMs" column. The testers described in those columns are only barely recognizable as being related to the ones appearing here. They were a machinist's delight, being about the size of your thumb. The disadvantage of these testers was based in that. I think that few TMs nowadays have access to a lathe or milling machine, and they tend to confuse the use of machine tools with the necessity of using machine tools. There was nothing in Dakin and Cox's articles that said that difficult machining was necessary, but the fact that it had been done that way made people shy off.

Anyway, slitless testers promptly faded into obscurity instead of taking over the "industry" (which is what I would have expected). Slitless testers were just so convenient — why did everyone ignore them? They were automatically aligning: you didn't have to work hard to make sure you go the knife parallel to the slit. They were bright: you didn't have to peer closely to see motes floating in your eye instead of the mirror. They were compact: you didn't have to worry about whether or not the slit and knife edge were too far separated (this is especially important in fast mirrors). Still, TM's forgotten about them.

Understanding how these testers work is easy: think of a knife divided into two parts, the lower half sitting over an illuminated region, the upper half sitting in front of your eye. When the image of the lower half is formed, it is reversed up-and-down and right-to-left. Thus we have, for example, a real knife on the left and an image-knife on the right, with the illuminated region in between. The tester is moved so that this illuminated region is squeezed between the real knife and the image-knife to form a "slit" with both edges being the same knife edge! That is precisely the way it works for non-aberrated systems. With mirrors that don't image light in the same plane (like a paraboloid at COC), we see a situation that is more complicated, but I have a discussion of this in the main article.

The only difference between these testers and the classical testers is that the moving source demands that the mirror pattern change twice as fast. For a paraboloid:

zonal tester measurement = $r^2/2R$.

I got interested in Foucault testers in 1978, when I saw how difficult published instructions were on making them. You either had to make a crude tester with a Barr scale, or make a "machinist's masterpiece." There was no middle ground. This was one of the prime hurdles to getting started in mirror making (the other being "Where do you get a barrel?"). I resolved to make a tester that I didn't have to be ashamed of without recourse to machine tools. The problem was split up into two parts: the tester proper and the kinematic stage. The first was solved early, with the construction in 1978 of a modified slitless Foucault tester, and the kinematic stage problem was solved between my 1980 and 1982 testers. It wasn't until 1983 that I discovered that Richard Berry had been working on the same thing. We arrived at essentially the same conclusion!

Don't ask me how to get a barrel — mine fell in my lap.

One other thing I'd like to say is that I liked the article on Newtonian collimation by D. Eric Allen. I especially agree with his statement that people have a tendency to blame poor telescope performance on anything except what is troubling it — bad alignment. I thought he came down a little hard on star test alignment, though. The star test was never intended as a stand-alone technique of alignment. First you align the telescope with the dots and then you must take it outside and give it a final "tweak" using the star test. The reason that this is mandatory for critical alignment is because mirrors (especially homemade ones) seldom have their parabolas precisely centered. They are like people wearing hats in this respect. Some have their "hats" on perfectly straight (not unlike Harry Truman) while others wear theirs with a rakish tilt. A "rakish tilt" for a mirror might be a 1/8" tilt at the focal plane — no big deal for an f/8 mirror, but fatal for an f/4. After you have given the mirror this final tweak, the diagonal, in principle, must be realigned, but you seldom disturb the system enough to make this necessary.

Dick Suiter
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Columbus, OH 43201

— Thanks for sending the corrections. If you have ever tried getting a set of equations through an editorial system, typed onto a word processor, edited, downloaded into a typesetting machine, and set in type, you can't imagine how frustrating it is. Our typesetting machine doesn't even have a "less than" sign, for example. Proofreading equations is tricky, especially when you consider how nutty all the different conventions used in math really are. Besides, the errors are invisible until the page is printed. I would appreciate seeing all submissions with equations submitted with the equations neatly typed with a clean carbon ribbon on a separate sheet of paper.

Tweaking the Diagonal

Dear Richard / In my article "Updating Newtonian Collimation," I was a little surprised at the addition of a third degree of freedom to the two listed for secondary movement. The point I was trying to make is that if the secondary holder, whether centered or decentered, is correctly made and the spider is mounted correctly, then tilt is not necessary. Since these criteria are not always met, it is nice to be able to compensate for it. BUT if you have a centered secondary and you find yourself tilting it away from the focuser to any significant degree, then you are almost certainly doing something wrong, like trying to compensate for the lack of offset, or for the optical illusion, which amounts to the same thing. This is not only unnecessary, but will make proper collimation impossible. I would guess that only a small percentage of centered-secondary Newtonians are correctly collimated, as this mistake is commonly made.

While I'm writing, I'd like to point out a minor inaccuracy in William T. Peter's Letter in TM#22. The values given for the diagonal minor axes are too small by a small amount; for example, a 16" f/4.5 with a 14" offset is assigned a 3.11" minor axis, which he indicated will fit an axial cone. The correct value to fit the axial cone is 3.14" for an offset diagonal (or 3.5" if you center it — a good

reason for not centered the diagonal in a fast system).

The discrepancy comes from the fact that the formula commonly used for these calculations gives the value for the width of the light cone at the intersection of the cone axis and the diagonal. This is not the same as the minor axis. The discrepancy is small, being only about 1% at f/4.5, and only about 6% at f/2.

Concerning diagonal size in general, a diagonal is like a diaphragm in a camera. If it is smaller than the axial light cone, it reduces the on-axis aperture. This is fine for a camera, but I consider it heresy for a telescope. If you wish to see an image produced by your full aperture, you will need more than a point at the focal plane — you will need a diagonal bigger than the correct minimum. I will have to agree with the old-timers on this point.

There are better ways of dealing with secondary obstruction than reducing the aperture. Assuming the problem is secondary obstruction and not collimation, you might get a shorter focuser as Peters mentions in his letter. In a telescope not yet built, you might want to get a longer focal length. I don't personally consider anything faster than f/6 to be a general purpose instrument. Those of us afflicted with aperture fever are restricted to short focal lengths because of the availability of reasonably-priced large optics and because of portability considerations.

Your suggestion of interchangeable front ends in the article on your 20″ (TM#7) opens up possibilities for fast systems. An alternate front end (diagonal, focuser, finder, secondary support) could be designed exclusively for planetary use, perhaps with a built-in Barlow, and would be easier to build than an interchangeable secondary system.

D. Eric Allen
1118 Swan Lake Rd.
Edmond, OK 73034

— I think we agree on tilt. I added tilt because it is a necessary third degree of freedom unless the diagonal is installed at exactly 45°; it is used only to correct the actual angle to 45°. It was added because without it, the implication is that tilt is an unnecessary mechanical adjustment.

Balancing Act

Dear Richard / I had just finishing designing my 17½″ Dobsonian along conventional lines when TM#17 arrived. When I reached page 4, I found I could go no further. I slowly reached for my original plans and neatly tore them in half. After many more days of drawing and calculating moments of inertia, I finally arrived at the final version which you now see.

Ivar Hamberg had done a marvelous job of designing his portable set-up, but I had some reservations about the light materials he used, especially the aluminum tubing. So I opted for ⅛″ wall rods which necessitated having a larger box and cradle. The box has ½″ exterior ply reinforced inside, while the cradle has 1½″ thick side panels and is supported front and back. The center pin has a machined bearing and the secondary cell was kept to only 7 pounds, including the secondary itself. Everything was screwed and glued for added rigidity.

When I arrived at the stage of drawing up the ground board, a problem immediately arose. The center pin which is placed at the center of gravity was offset from the physical center by over 2″ when three feet are used for support. This also means that the cradle sides are also offset by this amount, and when swung through 180°, there is quite some overhang. I then figured on using four feet, which for the lightweight design was all right, but might not be stable enough on uneven ground. The solution was simple but nowhere have I read or heard of it being done.

By lengthening one of the three feet, the actual center of gravity is moved back toward the physical center of the ground board. So all you have to do is find suitable ground of some 5″ in length for the ground board to be stable.

Like a lot of amateurs, I progressed from visual observing to astrophotography. Now my trusty 12½″ stays home more, while my 17½″ travels with me to darker skies. Unfortunately, my fellow astrophotographers now grumble continually, as they are tempted to spend more and more time viewing through the Dobsonian than watching guide stars. Oh well, seeing is believing.

Keep up the good work with TM, Richard, and pass my "Thank you" on to Ivar for his easily transportable, compact Dobsonian design.

Stephen Pattie
36 Newbury St.
Deep Park
Melbourne, Vic.
Australia 3023

Broken with Sledge Hammers

Dear Sir / With reference to TM#21, Letters on Lassell's telescope in Malta, the great speculum was broken up by sledge hammers when he finally demolished the telescope after unsuccessfully trying to present it to the Royal Astronomical Society. He lay on his sick bed within earshot of this sad demolition, according to King's *History of the Telescope*.

Mr. John Wall, FRAS
Optical Engineer, Old Royal Observatory
National Maritime Museum
Greenwich, London SE10 9NF England

Triplet Formulae

Richard / In response to several inquiries, I am making this information available to amateurs to help them construct lenses such as mine for their own use. This information is copyrighted by Dr. Leonard Larks and myself; it is available for non-commercial use only.

The genesis of this modified Cooke triplet was an article in the May 1967 *Sky and Telescope*, pgs. 312-319, by Mr. Donnel. International Glass made up several sets of glass for this expecting a surge of interest which never happened. One reason was that when analyzed, the system had too much coma. Dr. Leonard Larks, then a student in the optical design class of Citrus College, Azusa, CA, ran an optimization of the system which I fabricated. The glass is LBC-1 541/59.9 and DF-2 617/36.6. The above sources no longer exist; our instructor, Mr. James Kent, still does. He perhaps could supply you with the glass blanks as well as the radius plates. His address is: 861 E. Juanita, Glendora, CA 91740. Lest you get lost in all my figuring, the radii of curvatures in inches are:

Element 1 — Biconvex

R1 = 7.36106
center thickness = .6209
R2 = 58.23928

Element 2 — Biconcave airspace = 2.839

R3 = 6.120997
center thickness = .4294
R4 = 5.706197

Element 3 — Biconvex airspace = 1.617

R5 = 16.634388
center thickness = 1.0836
R6 = 5.092942

I undershot my center thickness on the center flint element as indicated in the worksheets. We re-ran the lens program to the fabricated dimensions, modified the airspace distances and reduced spherical aberration to 0.020. I did not aspherize R6, but it should be done. We never did know where to put the stop, but our guess was at R3, and the cell aperture there is 2.965". It seems OK at that.

You must notice that the first lens is very thin; we called it the elephant eye. As indicated in the worksheets, I finished it by hand work, with gloves for heat insulation.

After completion, the lenses were anti-reflection coated by a professional coater. I had a machinist, a very good one, design and make the cell out of aluminum, threaded inside and out to accommodate each lens holder and allow careful spacing. The collimation presented no problems from this very tight tolerance cell, but rotation of the lenses in their retainers was necessary for best performance.

A square aluminum tube was made to take a Graflex 4"x5" camera back I purchased second-hand. Squaring-on provision was made for the camera back, which turned out to be unnecessary since the end mounting blocks had been trued in a large mill. The forward mounting block was recessed to give a good flange all the way around for mounting the astrograph and to mount 35mm cameras on it. The outer barrel of the cell up front was inscribed in thousandths of inches to control focus, which varies .010 from blue light to red. Focus is stable over a large range of temperature, a surprise to me.

A slot was milled just ahead of the focal plane to accept Wratten 5"x5" gelatin filters mounted in cardboard — a UV filter always being necessary to eliminate large halos around star images, unless they are desired for dramatic magazine pictures which I have done on purpose sometimes. But proper use of spectroscopic emulsion, filter, and focus is necessary for sharp results. All metal parts were glass peened and black anodized.

I assume that you have a lens grinding-polishing machine and proper diopter tools, and testing equipment. We had all that at Citrus College Optical Shop. Home work on such a system would require a whole room full of such equipment. It would probably be easier to find such a shop than set up one at home.

This project took me two years with access to all the proper tools and supplies, but it was a very satisfying project to me. I enjoyed both the construction and now the use of the instrument.

You will probably have many more questions, so please write.

Rev. Ronald E. Royer
St. Pancratius Rectory
3519 St. Pancratius Place
Lakewood, CA 90712-1495

More Kiln Technology

Dear Mr. Berry / After seeing my letter on "Kiln Technology" in print, I realized that I left several gaps that need further explanation. The primary gap was in not mentioning the exact fusion temperature used. Pyrex starts to soften at about 710° C and reaches "fusion" temp at 740° C in a standard enclosed kiln. The 830° C temperature in the Hill-Angel designed kiln would cause a complete "meltdown" in an enclosed kiln common to most potters! That temperature is suited to the Hill-Angel method only.

There is also a lag between the temperature of the kiln "air" and the interior mass of the glass itself, so that in my successful attempt at firing a 24" blank (monetary restraints prevented a larger size at this time), and the previous 14¼", I held the glass at 750° C for 40 minutes, which provided ideal surface contact and produced very little discoloration (the murky-grey fog common on the composite blanks). Then I quickly dropped the temp to 700° C or so.

Another aspect is that in using the "spoke-wheel" design, the bottom plate need not be the same diameter as the front plate. In my 14¼", it is only 11", and in the 24" it is only 20½".This translates into a savings of glass, but means the construction of a well-designed nine-point (or more) support system is necessary. The glass need not be fire-annealed since it will be annealed once more, again resulting in cost savings.

With regards to the annealing, the range is 610° C to about 500° C. The ⅝" glass needs a longer time than the ½" used by Hill and Angel. In my own kiln, which has two circuits, I set one control on 5.0 (on a scale of 0 to 6.9). This setting allows just enough heat input that it took 3 hours 30 minutes to drop the required range. Each kiln has its own character in this regard, so try a few dry runs with scrap glass (e.g., build a cube) — unless you have access to a factory-built kiln with sophisticated controls, of course!

Throughout the project, the biggest problem was constructing the mold over which the 24" had to be slumped. The 25" diameter mold was made from low-shrinkage clay and crushed firebrick, producing a "grog" common to clay work, rolled out as you would bread, allowed to dry and then sanded down to a convex surface. Pyrex will not stick to kiln firebrick, though plate glass will. This mold was fired to 740° C and the curve redone since the edges tend to swell up a bit at the required temperature. The internal supports — carved or cut firebrick — ought to have as low overall mass as possible without crumbling. It is very fragile, but can be filed down to allow easier heat penetration: try to core out any large volumes. At 750° C, Pyrex glass becomes like taffy, so support is needed in a few points. Here the spoke design allows the supports to "lean" against each other in a circle, and the design allows for easy extraction as well. They can be used again if built in, say, two or more sections.

Finally, the initial heating, from 0° F to about 500° F for ⅝" glass, took me about four hours. If heated too quickly, the glass will crack due to stresses between the internal temperature and the warming exterior. If in doubt go slow! Stay for 20 minutes at, say, 150° F, then again 20 minutes at 225° F. Once the temperature stops rising, add a bit more heat. Once above 650° F, kilns generally take a while to rise in temperature on their own. My own cycle from 0° C to 750° C takes nine hours, then 3 hours or so for annealing, and then everything cooks on its own.

One additional point. In the 24", the ribs were not cut with a curve in them; the whole thing was heated and fused in one firing. Instead of having a curve on the ribs, they were tapered so that in the overall length of 10⅝", one end was ⅜" less in height than the other end. The tapered end is positioned toward the center, so that as the glass slumps in the kiln, the ½"-thick bottom plate comes out relatively "flat," while the front plate, ⅝" thick, is curved.

Letters

The procedure sounds complicated, but the results were spectacular, and it is a lot easier than it sounds. Everything is basically an engineering problem; if taken in steps it is easily accomplished. The only mystical part was finding the best temperature at which to fuse the pieces together — and that magic number is 750° C for 40 minutes in my furnace.

Richard Rokosz
23 Lamont Ave.
Agincourt, Ontario
Canada M1S 1A8

Sliding Roof Mechanism

Dear Sir / I recently built a small 5'x6' backyard observatory. Since the yard is small, I didn't want to add the usual additional frame for the roof to slide on. Instead, I bolted legs on the roof itself so the roof is free-standing when pulled back off of the observatory housing.

The slide mechanism consists of narrow aluminum U channels which nest inside of each other. The narrow channel is fastened to the roof and rides inside a wider channel fastened to the building. An occasional squirt of silicone spray keeps the sliding friction to a minimum. Also, filing the ends of the upper channels into a curve prevents binding or "digging in" as the roof is opened or closed.

Howard E. Lazerson
8540 So. Sepulveda Blvd., Suite 1115
Los Angeles, CA 90045

Semi-Automatic Lens Design

Dear TM Readers / In the last couple of issues of TM, readers have expressed an interest in telescope design by microcomputer, and apparently some microcomputer programs are now being written for lens designers. Four years ago I wrote a simple program for semi-automatic lens design which, I feel, could be used by amateur astronomers. The program is written in BASIC, requires only 10k bytes of memory, and is quite fast. It can serve as an aid in lens design and could be useful as an instructive device for those wishing to learn something about lens design. I would be happy to make a listing of the program available (free) to anyone who is interested. Just send me your name and address.

Bill Mckinley
5019 16th N.E.
Seattle, WA 98105

Getting Lined Up

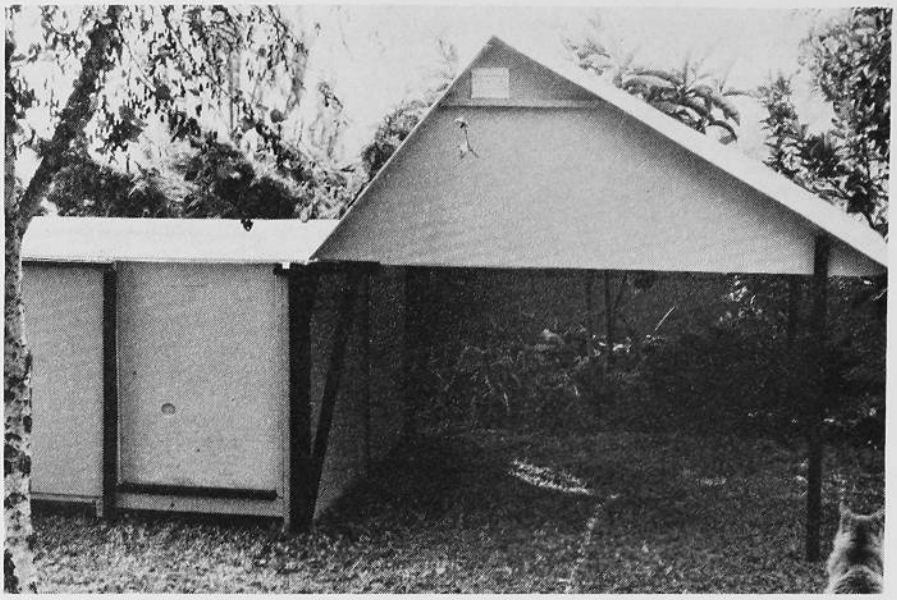
Dear Richard / I want to thank you for the continuing guidance provided me in the pages of TM and ASTRONOMY magazines. I keep them in binders, and they are an active part of my astronomy library. The best praise I can give you, however, may be in the form of a subscription renewal — here's mine for two years. If you had a box for 3 years on the form, I'd have gone for it. Keep up the good work.

I was pleased to read D. Eric Allen's article on collimation in TM#22. No truer words have been spoken. Collimation is hypercritical with today's fast (f/4.5 and faster) optics. I use a center dot ⅛" in diameter on the primary of both my 13.1" and 8". In conjunction with the dot, I use a collimating eyepiece from Telescopics, which I further modified by polishing off the bottom flat (circular) edge, removing the black finish. This surface, when viewed through the hole in the center (reflected off the mirror), creates a clearly visible circle within a circle, creating a neat bulls-eye effect — perhaps not quite as precise as the tube/crosshair device, but quite simple and effective. Images have improved considerably. It is my most-used accessory.

Thanks also for the articles on eyepieces in TM#19, 20, and 21. I hope other, more detailed articles will appear in future issues. Eyepieces are the singularly most generally ignored subject in the literature. I don't care how perfectly figured the mirrors are, if the eyepiece is of poor quality, so will be the image you see through it. Worse, I suspect that because of lack of information, a lot of good/excellent telescopes are blamed when the optics at fault are those held by the focusing mount. I'm not the only one who has noticed the superior quality of TeleVue eyepieces. So have you, Rutten, and van Venrooij, and others as well. The array of eyepieces now being sold is absolutely awesome, and each maker claims theirs to be either the best or equal to the very best. Most of the time it is not true, and it is particularly important when buying eyepieces to use with fast optics that only the best be used. More information/testing, please.

And I'll keep renewing.

Jan Owen
9007 W. Clarendon Ave.
Phoenix, AZ 85037



Buchroeder (left) and Dall (right) discuss a twitcher. See TM #21, pg. 6 for the article.

Missing IDs Provided

Dear Readers / Just a quick note to mention I have had several inquiries about the picture in my article asking, which one of them is Horace Dall and which the well-known optical expert Dick Buchroeder. Dall is the one on the right, holding the telescope, and Dick Buchroeder is on the left.

I had a letter from Buchroeder today in which he notes: "Well, I see I got my picture with Horace Dall in the current issue of TM, as well as a mention by John Gregory! I'm beginning to feel old, what with all this publicity."

— Bob Cox

Less Flat Window Required

Dear Mr. Berry / Gregory Reeve ("Ultimate Newtonian," TM#23) states that both sides of a borosilicate optical window must be flat to considerably better than ¼-wave. Jean Texereau, in the new second English edition of *How to Make a Telescope*, page 197, clearly shows that this is excessive.

The simple 1-2-3 method, described in ATM-volumes, will insure sufficiently plane surface of an optical window, and a micrometer, the required parallelism of both sides to avoid significant chromatic error.

There is also a cheaper and simpler solution to a Newtonian, intended for planetary and lunar observations: an off-axis aperture mask! With Dobsonians 12" or larger, these masks can give 6-inch f/10 unobstructed apertures, with all the advantages of the reflector (including the low price) remaining. At the same time, you only have to lift off the mask to have all the advantages of a fast, low-power, deep-sky instrument.

Mladen Vranjican, M.D.
63-141 Alderton Street
Rego Park, NY 11374

Apodizing and Metzger

Dear Richard / I thoroughly enjoyed your article in the latest issue of *Telescope Making* and was glad to see your comments about the use of the apodizing or glare screens. Regarding the "controversy" as to whether or not the screen improves the seeing conditions, I think the answer is twofold. The screen does not directly modify how we see turbulent or blurred images, but does modify it indirectly resulting in a real improvement. W.H. Pickering pointed out many years ago (ATMII: "Refractor Versus Reflectors") that diffraction rings were very susceptible to atmospheric turbulence, especially the first ring. With large central obstructions giving bright first rings, atmospheric turbulence could cause the ring and the central disk to merge causing a loss of resolving power over a much larger extent; the loss of contrast would also be considerable. The screen modifies the rings in both the refractor or reflector images by suppressing them. By doing so, turbulence essentially affects the disk only, causing the eyes to interpret this as an improvement in seeing. This being the case, the eye should interpret an improvement of *apparent* seeing to a greater extent with a reflector than a refractor, since the refractor's rings are dimmer to begin with. This is exactly what you get — the improvement is more noticeable in the reflector.

Regarding Hal Metzger (whom you mentioned): he was born in 1899 and died May 2, 1976. He was a radio station manager and program director in Ohio until 1949, then moved to Alfred Station, N.Y., where he and his wife operated a small gift and art shop called "Glidden Galleries." Subsequently (except for a brief time in Ja Jolla, California), he lived in either Alfred or Alfred Station the rest of his life. In 1947, he joined Walter Haas's newly formed A.L.P.O. and was a charter member. In the 1940s, he started experimenting with what he called "glare screens" and in the early 50s marketed them in S&T through "Sky Gazers Exchange" (you could then sell commercially in that column). About this time, he became acquainted with Norm Edmund of Edmund Scientific. He tested and evaluated 3" and 4" objectives that Edmund was planning to use in marketing their then soon-to-be-announced refractors. Subsequently, Edmund took over the marketing of the "Metzger Glare Reduction Screen" and sold it from 1954 to 1967 in two sizes — 4" and 6".

I wrote a paper on the glare screen for ALPO in 1962 and Metzger contacted me. We began a series of letters (as many as three or four per week and sometimes 20 pages long) that lasted until his death. He was my mentor in lunar and planetary observing.

He owned and used over 60 scopes in his life. In the early 1970s, he donated his 4" Bausch & Lomb refractor to Alfred University where today it is a guide scope on a 16". He was also instrumental in the rejuvenation of the astronomy department at Alfred U. (9" refractor, 16" and 20" reflectors). In 1975, the university honored him by creating the Hal Metzger prize in astronomy to be awarded on an annual basis. He had no general preference for refractors over reflectors, or vice versa. During the last 10 to 12 years of his life, he used mostly a 6" f/12.5 Newtonian with a small diagonal. For larger scopes, he used the instruments at the University. Some years before his death, he donated the "Strolling Astronomers" that he had accumulated between 1947 and 1961.

Hal was not one for publicity. He attended conventions infrequently and was content to remain in the background, but had a storehouse of optical and observing knowledge that was enthusiastically given to anyone in his very quiet, unassuming way. I lost a damn good friend when he died and it was very rough going out to the mailbox knowing there wouldn't be any more letters coming from him.

We would often compare observations made on the same night, even though we were separated by about 400 miles. Hal was a member of the "old school" (so am I) who believed that telescopes were made to look through and you didn't need cameras or fancy gadgets attached to them. He, as a visual observer, was on a par with the best ALPO had to offer. As an artist who had won major awards, he had no difficulty conveying on paper what his eye discerned in the scope. He once sent me drawings that he and the late Matt Taggert had made of Mars in 1954. I drooled at those drawings, which he wanted returned so I don't have them.

He told me that systematic lunar and planetary observing was the most difficult type of program for an amateur to take up because it requires a certain type of temperament to keep at it. I concur wholeheartedly. But even though it requires perseverance and patience, the rewards are great, for it is the only branch of amateur endeavor that deals with more than just points of light. Despite this, his favorite object was M-13. It was the one he relaxed with after lunar or planetary observations, or looked at if seeing was poor but transparency was good.

Rodger W. Gordon
637 Jacobsburg Road
Nazareth, PA 18064

— Thanks for the background on your friend Hal Metzger. I am glad to know who he was, what he did for amateur astronomy, and how "Metzger Glare Reduction Filters" came to be.

On the utility of apodizing, even skilled observers' opinions vary (see the next letter). I would like to introduce the term "Perceived Image Quality" into the literature to describe what people say they see. So rather than saying "the seeing was improved" you would say "on a night of poor seeing, PIQ was improved." Regarding my comments in TM#23, it must be remembered that the seeing was very poor at Riverside. Here in Milwaukee under less transparent skies but far better seeing conditions, apodizing has far less effect on PIQ.

I still don't think an image quality model based on broken first diffraction rings is powerful enough to describe the influence of apodizing screens on low-contrast planetary detail. I think we're doomed (if that's the right word) to examining it in terms of MTF or other more sophisticated methods of analysis. Steve Edberg's article is the first step toward a fuller understanding (for amateur astronomers) of what these devices actually do.

Although Edberg is annoyed by my suggestion in TM#23 that an apodizing screen would be a useful addition to every observer's accessory box, I'll stand by that statement. Even if they get used only once a year, it would be nice to have an apodizing screen close at hand on that occasion. However, if what Edberg describes can be replicated, a neutral density filter would take up considerably less space and accomplish the same thing.

And Without the Screen...

Dear Ricardo / At Riverside 1983, after 4 years of trying, I got a long look through Leonard's Yolo without the screen. He had set it up, adjusted the harness, and then God smiled and Art was called away for 20 minutes, so I commandeered the scope selfishly and got what I wanted. The image of Saturn was better than refractor sharp; the contrast was fabulous, more like a drawing than a telescopic view. This finished a "drive" that I started in 1957 when I first encountered his ideas.

When he came back, he scowled at me and hastily put on the screen. The edge was a bit sharper with the screen, the more obvious cloud belts sharper, but the areas of low contrast were all washed out. I preferred the unapodized image. Armchair logic is a powerful tool, but when it fails, one does not conclude it is wrong — rather that it is yet incomplete. Increase your attempts to get a look through the Yolo without the screen. Thank Rosemary — I finally got TM#21 yesterday. SALUD

Twinky
(Walter Scott Houston)

■

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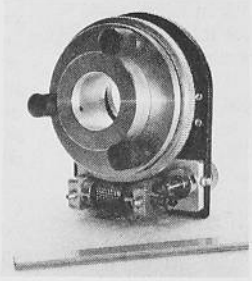

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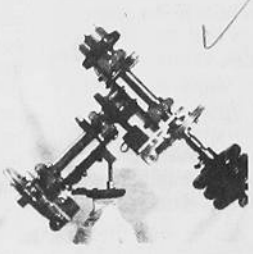

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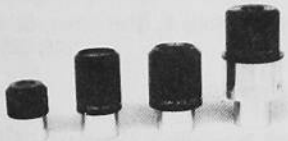

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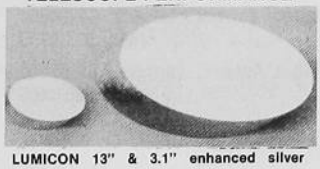

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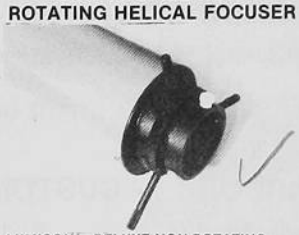

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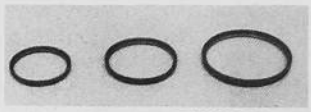

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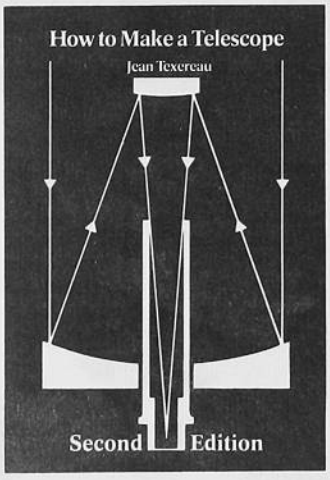

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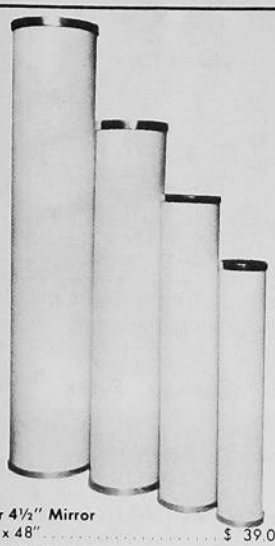

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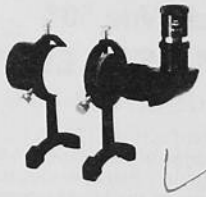

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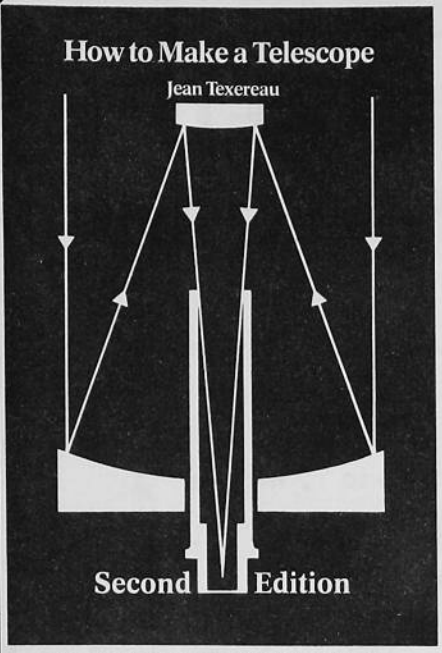

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ASTRONOMY magazine, May 1982

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From the Foreword to the First Edition
Albert G. Ingalls
Editor: *Amateur Telescope Making I, II, and III.*
Scientific American magazine

I owe a lot to the first edition. My first mirror, begun when I was 13 years old, was a trial and error effort; and indeed, the whole project might have ended in failure had a local telescope maker not taken the time to show me how to parabolize it. My second mirror was figured to a fine paraboloid; finding Jean Texereau's book made all the difference. Since those first mirrors, I have gone on to make a dozen more, taught mirror-making to others and built many telescopes, but I still turn to Texereau.

From the Foreword to the Second Edition
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Editor *ASTRONOMY* and *Telescope Making* magazines

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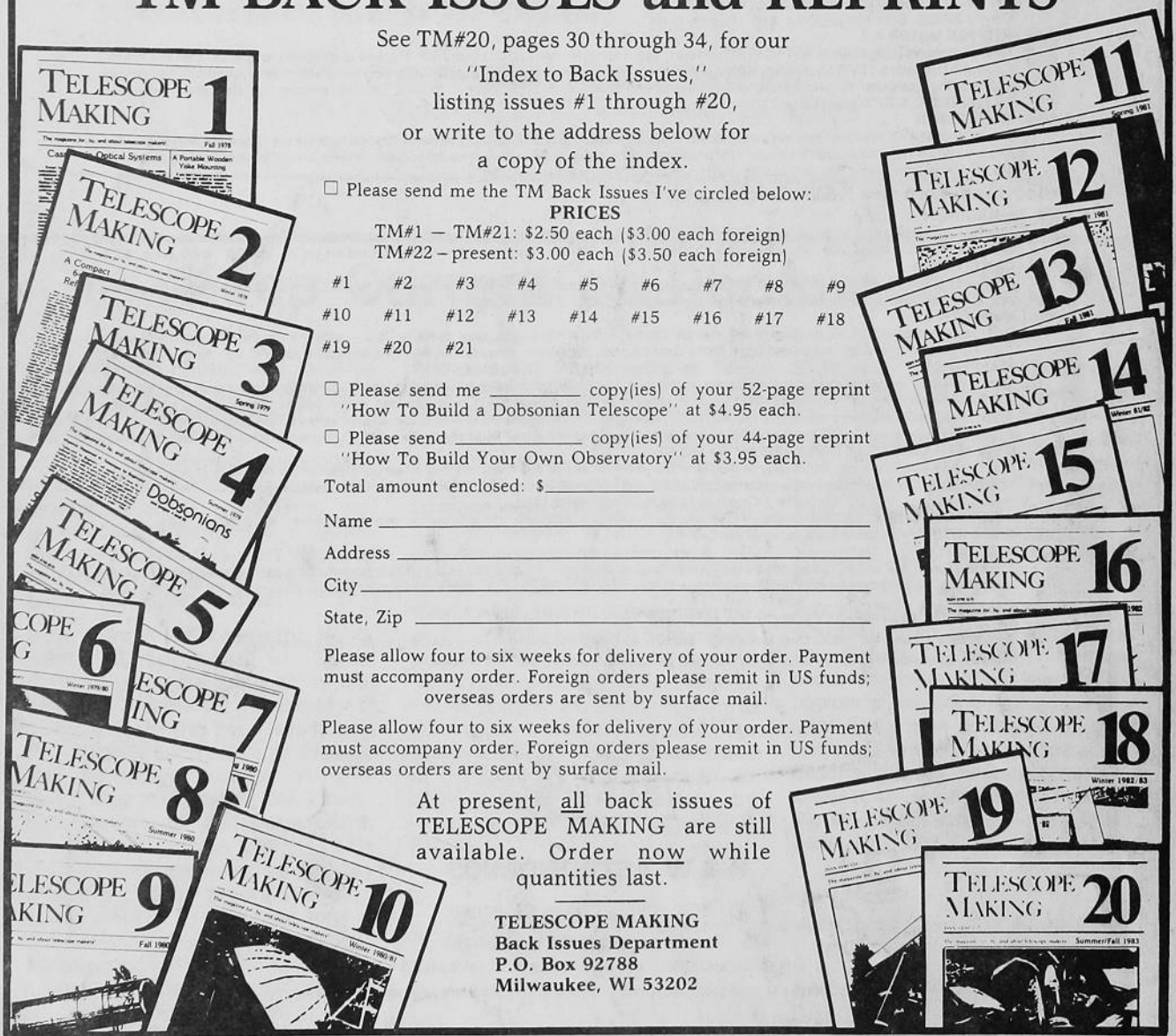

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